Air & Space

National Air & Space Museum
Smithsonian Institution

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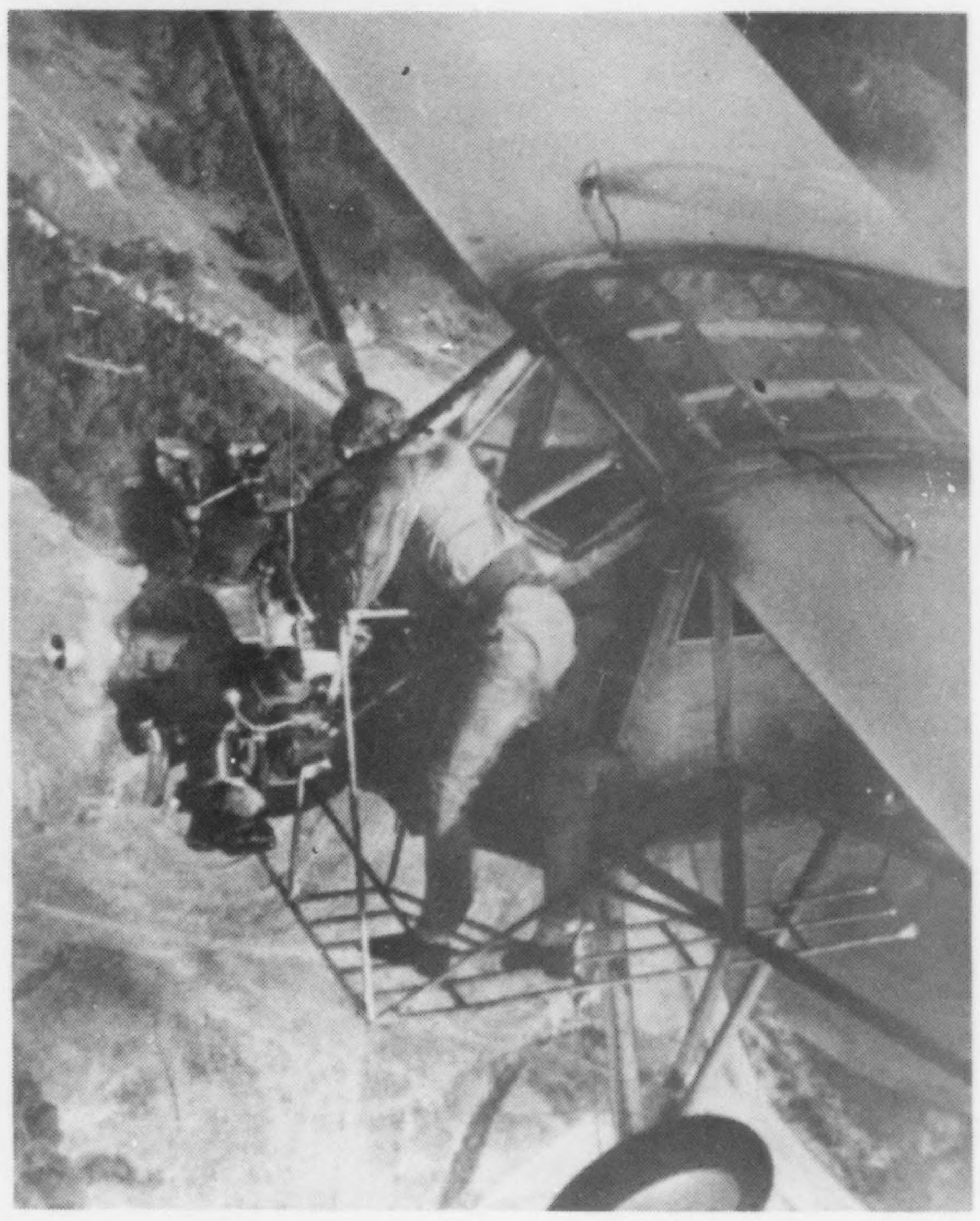

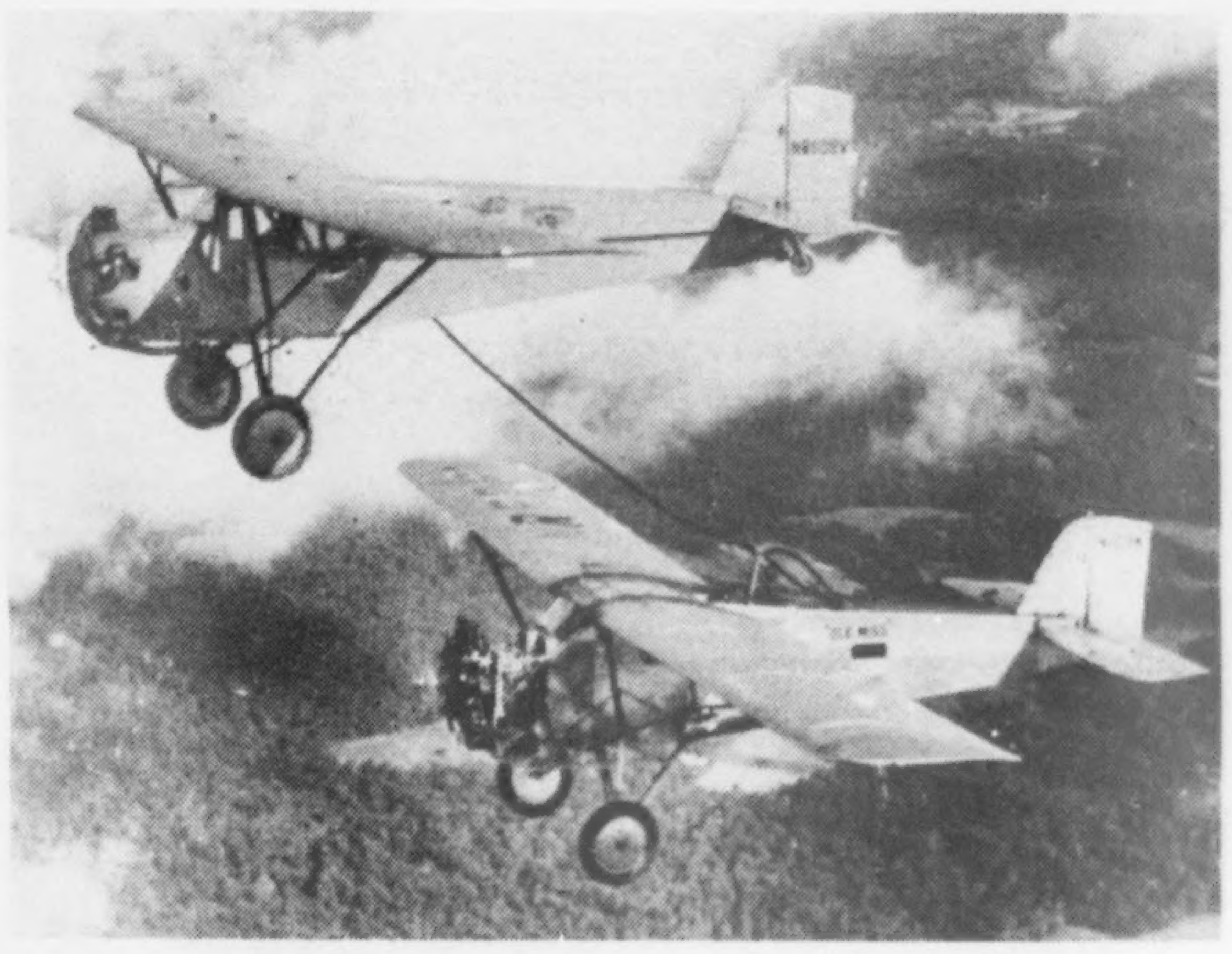

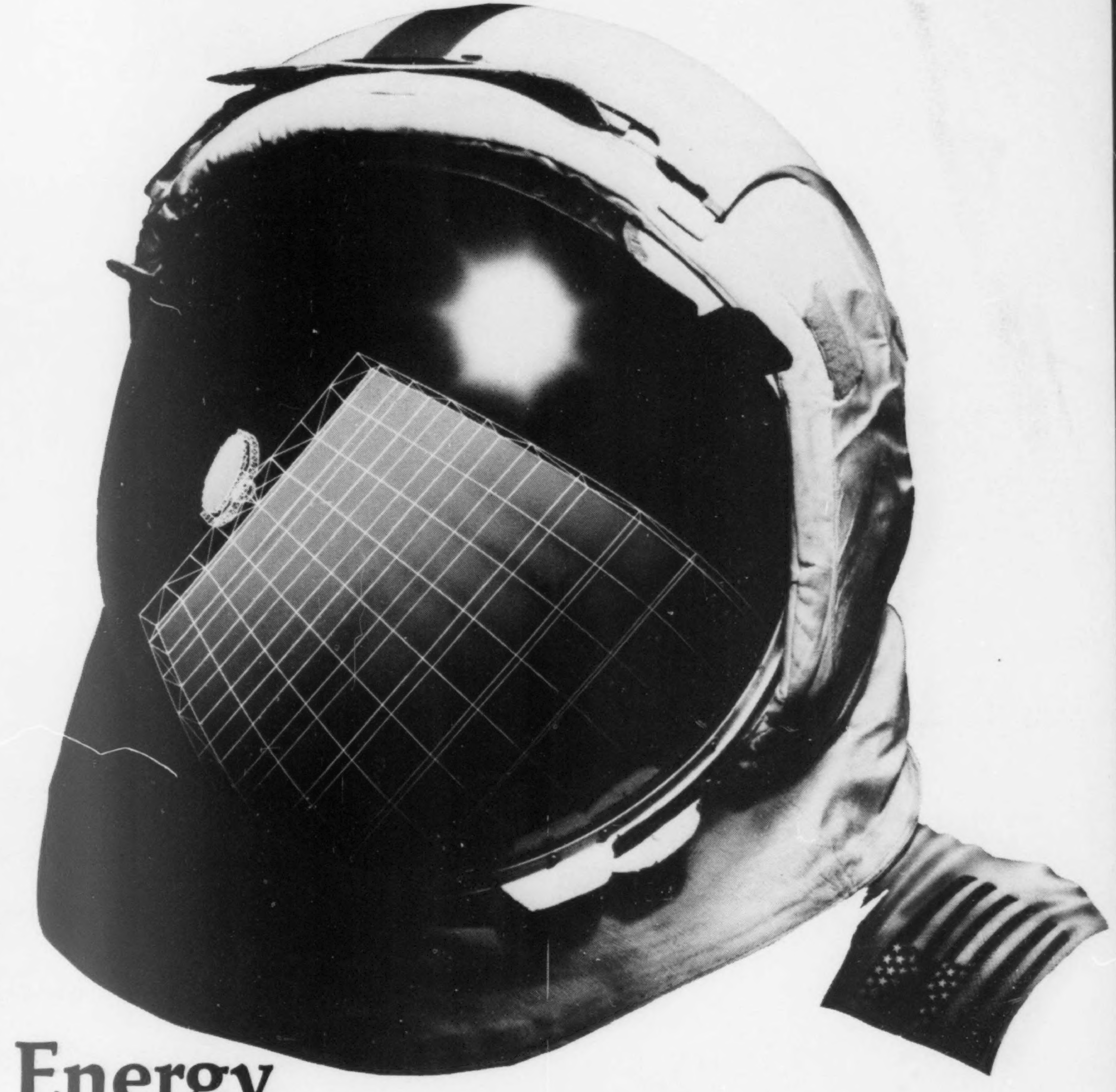

Energy

Keeping the engines running

At 12:32 p.m., June 4, 1935, Fred and Algene Key took off from Meridian, Mississippi, in a 1929 Curtiss Robin they had named Ole Miss. When the Key brothers landed—on July 1—they had set a new flight endurance record of 27 days, 5 hours, and 34 minutes. (Ole Miss now is in the collection of the National Air and Space Museum.)

During the flight, the intrepid pilot-mechanics conducted limited inspections and maintenance of the airplane's engine from a special catwalk (top left). Keeping the engine running was a greater concern than obtaining gasoline for it; at regular intervals, James H. Keeton and W. H. Ward, Jr., refueled Ole Miss in mid-air from another Robin (lower left).

During the endurance flight of Ole Miss, it seemed—to the weary pilots, at least—that the airplane would fly forever, supplied with a limitless flow of fuel. Today, however, the petroleum supplies on which we depend are quickly running out. We must conserve what we have, and find other sources of energy.

One ambitious alternative energy concept under serious study is the solar power satellite (SPS), which would convert solar energy to microwave radiation that would be transmitted to receiving antennas on Earth for conversion to electricity. (Right, an artist's conception depicts a hypothetical SPS station reflected from the helmet of a future space construction worker.) This enormous project, say its proponents, could generate up to 20 percent of our nation's electricity, at competitive prices. Many questions must be answered, and problems solved, before actual development of an SPS project could be started, however. More, page 12.

SCAN

For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.

Air & Space, a mini-magazine for educators, is published every other month, September through May, as an outreach of the National Air and Space Museum, Smithsonian Institution, Washington, DC.

Air & Space combines information from many sources for a condensed overview of the history, science, technology, and social impact of selected aviation and space subjects.

MUSEUM HOURS

Until March 31, the Museum will be open from 10 a.m. until 5:30 p.m.; from April 1 through Labor Day (September 3), Museum hours will be 10 a.m. to 9 p.m. The Museum is open to the public every day of the year except Christmas.

Correction

The Solar System Statistics chart on page 11 of the November-December 1979 issue of *Air & Space* included a typographical error. The period of rotation of Pluto actually is 6.39 days, not .39 days as published in the chart.

PHOTOCOPYING PAGES

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In view of financial limitations, Air & Space **is not accepting any new registrations at this time.**

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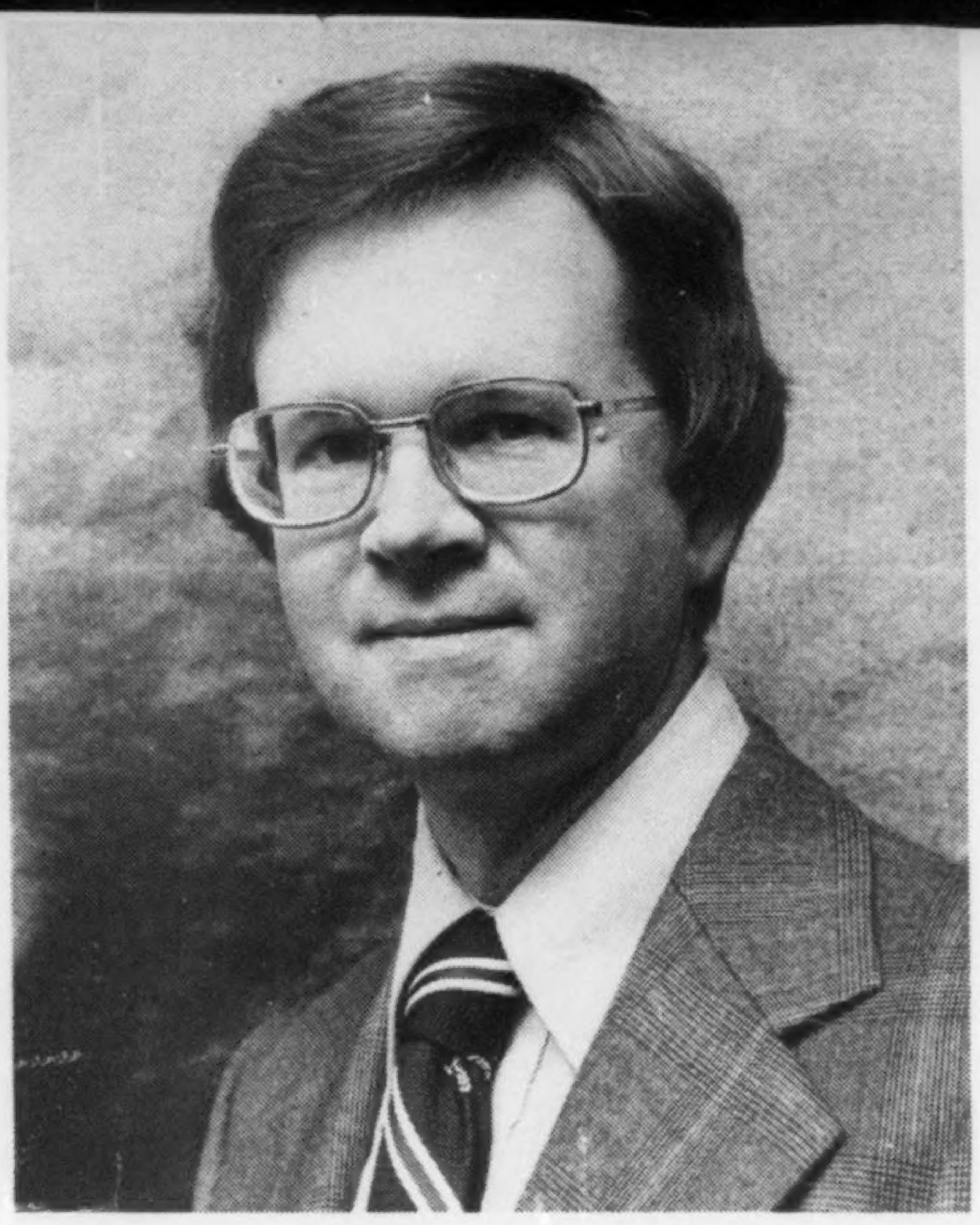
Briefing



Noel W. Hinners
Director, NASM

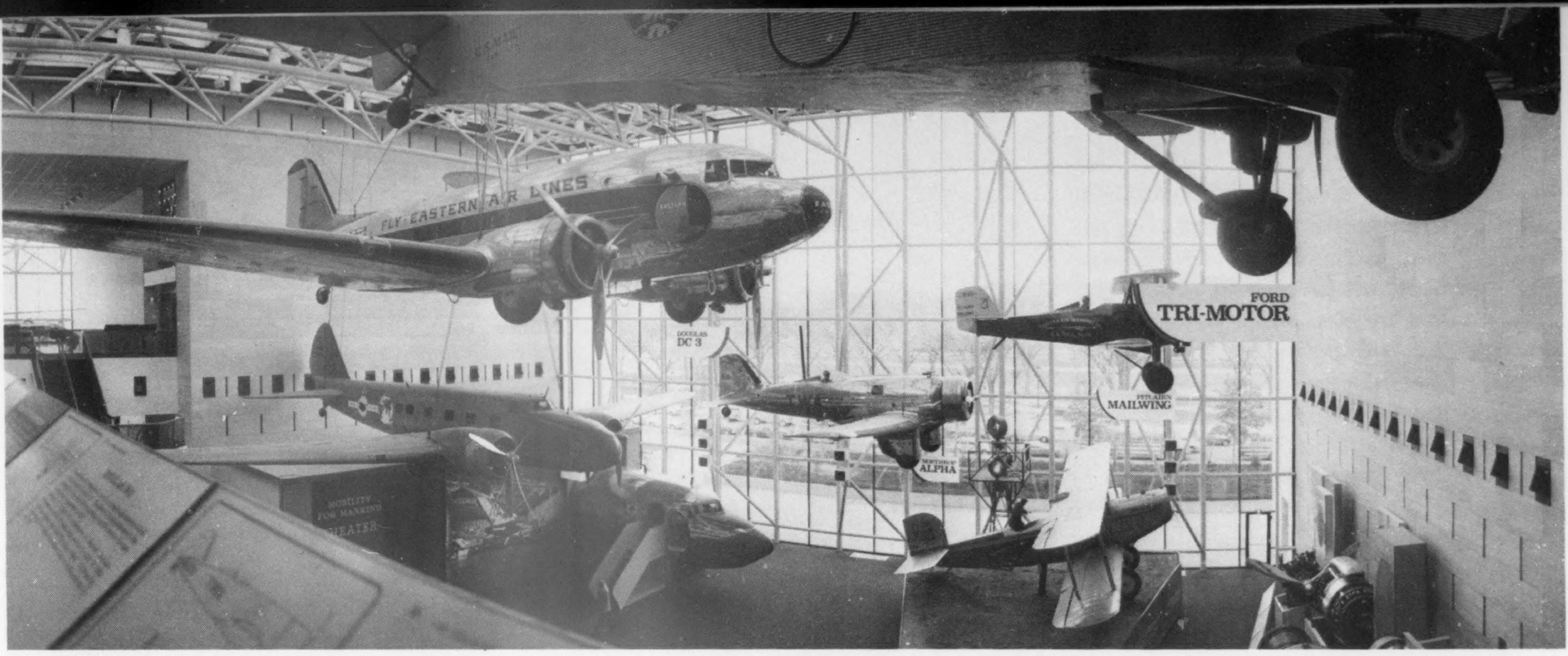
Museum—the word seems to say so much, and yet today there probably is less agreement about its meaning than our friend Webster implies: "**1.** obs. a scholar's library **2a:** an institution devoted to the procurement, care, and display of objects of lasting interest or value **2b:** a room, building, or locale where a collection of objects is put on exhibition" (*Webster's Third New International Dictionary*). These definitions well define the museum at one end of the spectrum, one that has a virtually invisible curatorial staff, quietly conducting research on obscure topics or collections, and whose public exhibit area consists of little more than thousands of assorted tidbits from antiquity, perhaps housed in a glass showcase and described in small type on an index card.

Webster's definitions have almost no relevance to the museum at the other end of the spectrum—the museum of science and/or technology. This kind of museum is, typically, a creation of the last several decades; as often as not, it has no collection of artifacts, no curator in the traditional sense, and isn't too concerned with history. Its strength is generally in the demonstration of principles of science and technology, frequently utilizing innovative exhibits techniques that involve audience participation and utilization of a full range of the human senses. Indeed, some of these new museums are so unlike traditional museums that they call themselves such things as "hall of science" or "science and technology center." They even have their own professional organization, the Association of Science and Technology Centers.

What has all that to do with the National Air and Space Museum? Lots, I think, because we need to combine elements from both ends of the spectrum and not be constrained by definitions or preconceived notions. We're in the fortunate position of caring for some of the most fascinating artifacts of all time, most of which are fewer than 100 years old. Many (especially those related to space) are fewer than 25 years old, and some, such as the Gossamer Condor, not yet three. On the other hand, it is largely the advent of high technology and the pursuit of science and exploration that has caused or enabled many of our artifacts to come into being. Political, military, scientific, and commercial needs frequently pushed technological development. It seems to me that all of these considerations are as important as the artifacts themselves and represent a story that needs to be told to the public. To the degree that we elect to tell that story, we can be thought of as an aerospace science and technology center.

To combine the historical museum artifact approach with the visitor-participation approach of the science and technology center is not simple. Science and technology centers typically cater to small numbers of visitors. But with our large crowds—the largest of any museum in the world—we could easily cause rank frustration by overdoing visitor participation, causing long lines for the visitor and extensive labor on our part. It is also one thing to demonstrate a scientific principle, quite another to show in a simple, interesting and informative way how that principle enables one to accomplish a complex task—for example, how to navigate a spacecraft to Saturn or to land an airplane completely automatically in zero visibility.

Rather than throw up our hands in despair, we like to look on these problems as challenges. To meet these challenges (see Mel Zisfein's article, "Creating a New Gallery at the National Air and Space Museum," pages 10-11) requires the best possible input from our own curators, exhibit designers, and educators, and a realization that frequently we'll have to go outside the normal museum community to get additional information and talent.



The National Air and Space Museum's Air Transportation gallery summarizes the evolution of the modern airliner at a glance.

Cleaning Up Their Act

how aeronautical engineers developed more fuel-efficient airliners

The first scheduled airline flight in the United States was made on January 1, 1914, when an open-cockpit Benoist XIV flying boat operated by the St. Petersburg-Tampa Air Boat Line carried a lone passenger across Tampa Bay from St. Petersburg to Tampa, Fla. During the first 10 days of operation, the fledgling airline flew 1098 kilometers (682 miles), carried 52 passengers (one at a time), and burned 720.9 liters (170.5 gallons) of gasoline, thus obtaining 1.5 passenger-kilometers per liter (4.0 passenger-miles per gallon, or pmpg).

By 1957, American air transports had achieved a nearly 20-fold increase in this figure: the sleek Lockheed L-1049H Super Constellation, with every seat filled, could attain 78.5 pmpg.

How did this enormous increase come about? Many technological advances contributed—improved fuels, more efficient powerplants, better weather reporting and forecasting, and more efficient air traffic control and route management.

Two of the most important areas of refinement were aerodynamic and structural design. Engineers strove to increase the lift produced by wings, reduce the drag (air resistance) created by the entire aircraft, and improve structures so that the same strength could be obtained from less aircraft structure weight.

Four basic forces—lift, thrust, weight, and drag—act upon an airplane in flight. To sustain flight, lift produced by air flowing over and under the wings must equal or exceed the weight of the entire aircraft. Similarly, the thrust of the propulsion system must overcome the airplane's drag.

Drag is the resistance of the surrounding air to the motion of an object through it. Aeronautical engineers concern themselves with three types of drag:

1. *Form* or *profile drag* is the resistance of the air to the *form* or shape of an object passing through it.
2. *Friction drag* is caused by air flowing across (parallel to) a surface.
3. *Induced drag* is a result of the generation of aerodynamic lift by air flowing over and under an airfoil; it is sometimes called "drag due to lift."

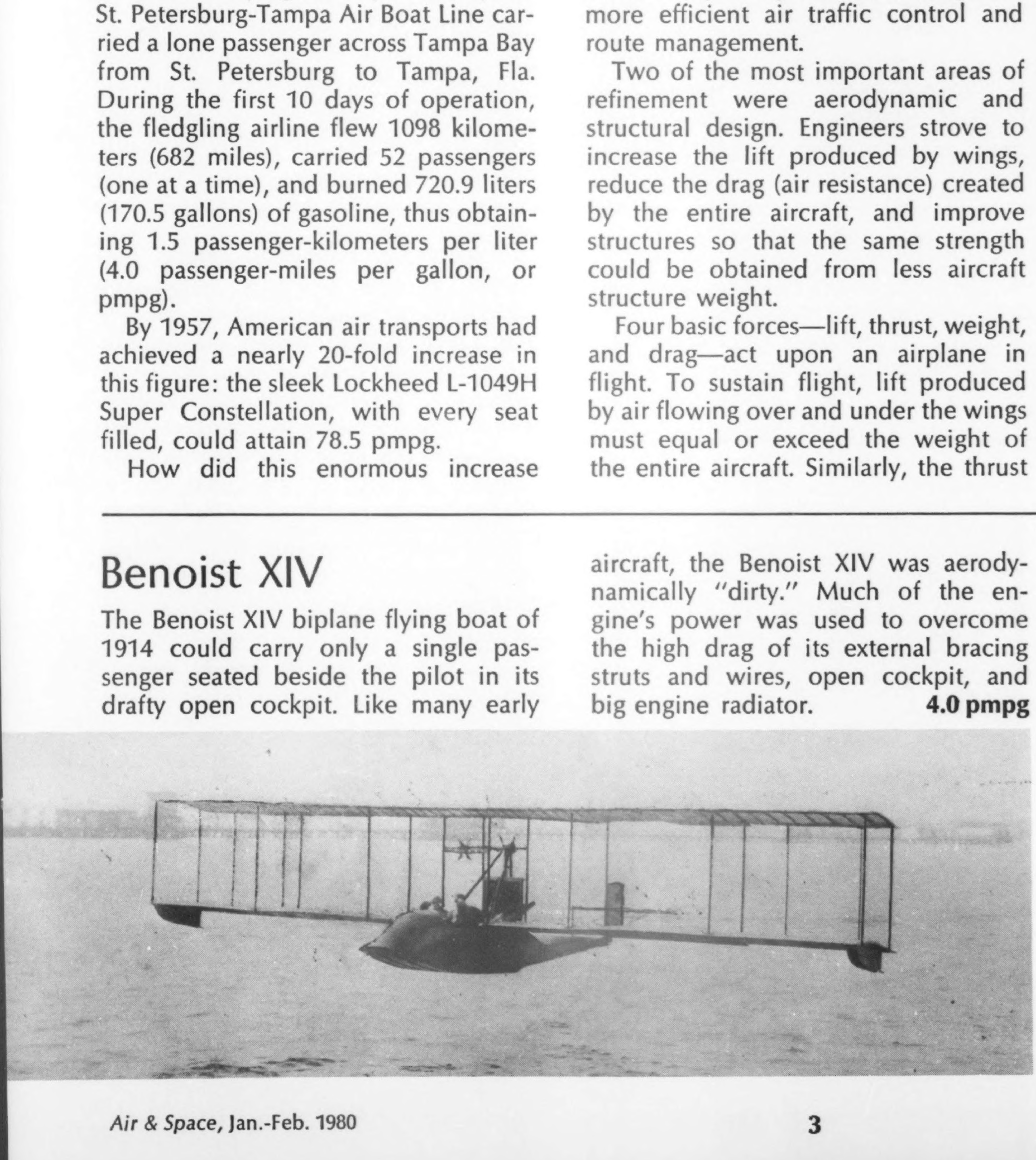
Aeronautical engineers sometimes refer to an airplane design having relatively high drag as being "dirty," and one that is well streamlined as being "clean."

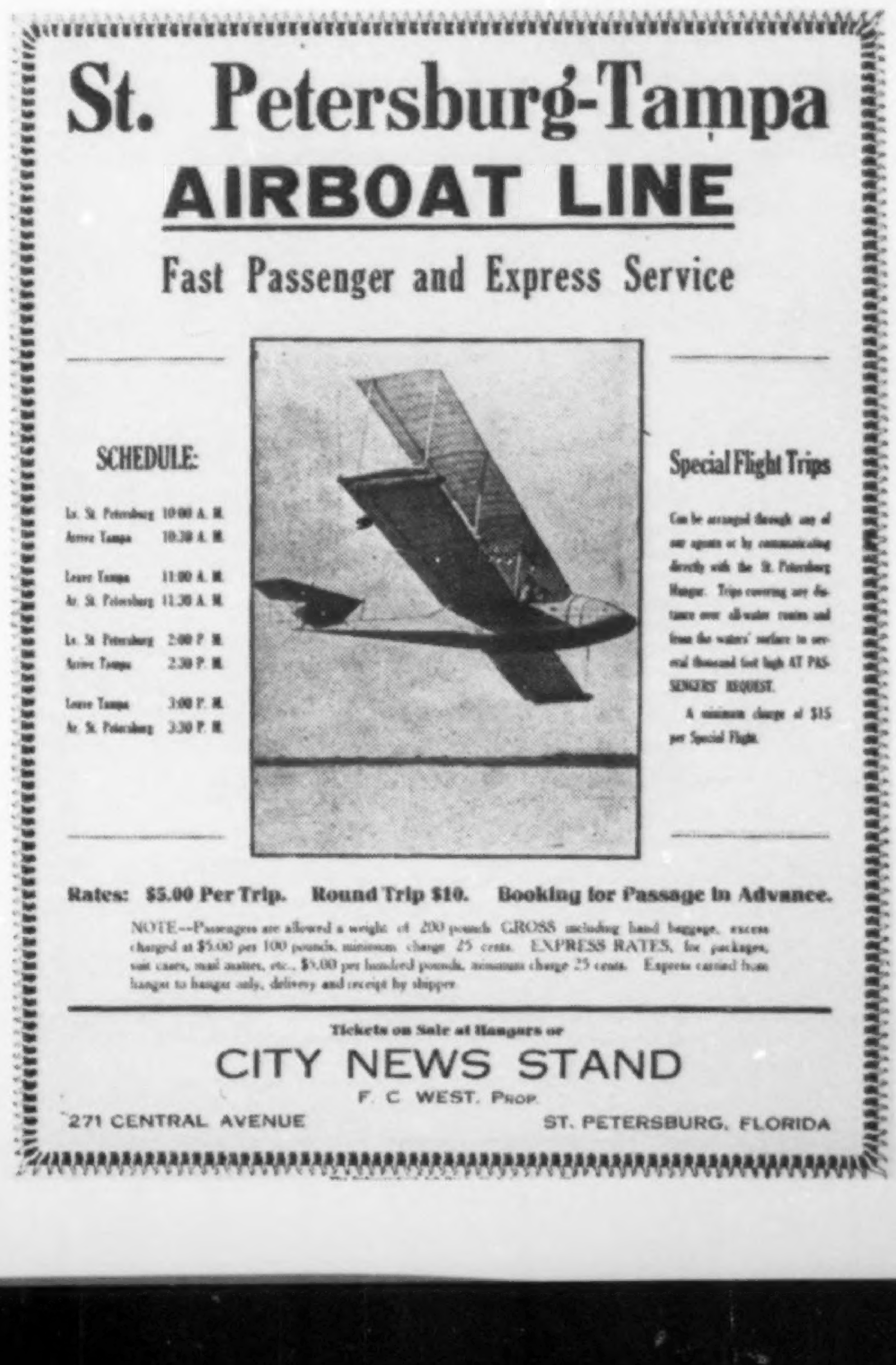
Put in its simplest terms, then, and ignoring other important design considerations (cost, aesthetics, ease of maintenance and flying qualities, passenger comfort, etc.), increasing lift and thrust and reducing weight and drag—without compromising safety—

continued on next page →

Benoist XIV

The Benoist XIV biplane flying boat of 1914 could carry only a single passenger seated beside the pilot in its drafty open cockpit. Like many early aircraft, the Benoist XIV was aerodynamically "dirty." Much of the engine's power was used to overcome the high drag of its external bracing struts and wires, open cockpit, and big engine radiator. **4.0 pmpg**





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make an airplane design more fuel-efficient.

On these pages are a few of the most notable aircraft representing milestones in the development of more efficient fuel use in air transportation. The figures given for fuel economy reflect ideal conditions—every seat filled, no wind, and no air traffic delays—and do not count the flight crew among the passengers transported.

Ford Tri-Motor

First flown in airline service in 1926, the Ford Tri-motor incorporated several drag-reducing advantages over earlier craft like the Benoist XIV. The Tri-motor transported up to 12 passengers in an enclosed (albeit noisy) cabin. The Tri-motor's cantilevered (supported at only one end) monoplane wing was more efficient than the Benoist's biplane configuration, because it eliminated drag-producing external wing bracing. **26.1 pmpg**

N9683
Ford
AMERICAN AIRWAYS
U.S. MAIL

Fairchild FC-2

Like its contemporary, the Ford Tri-motor, the 1927 Fairchild FC-2 monoplane boasted a monoplane wing (in this case, semi-cantilevered) and an enclosed cabin. Seating the passengers in rows running the length of the airplane made for less drag per passenger than the side-by-side seating of the Benoist XIV. **44.3 pmpg**

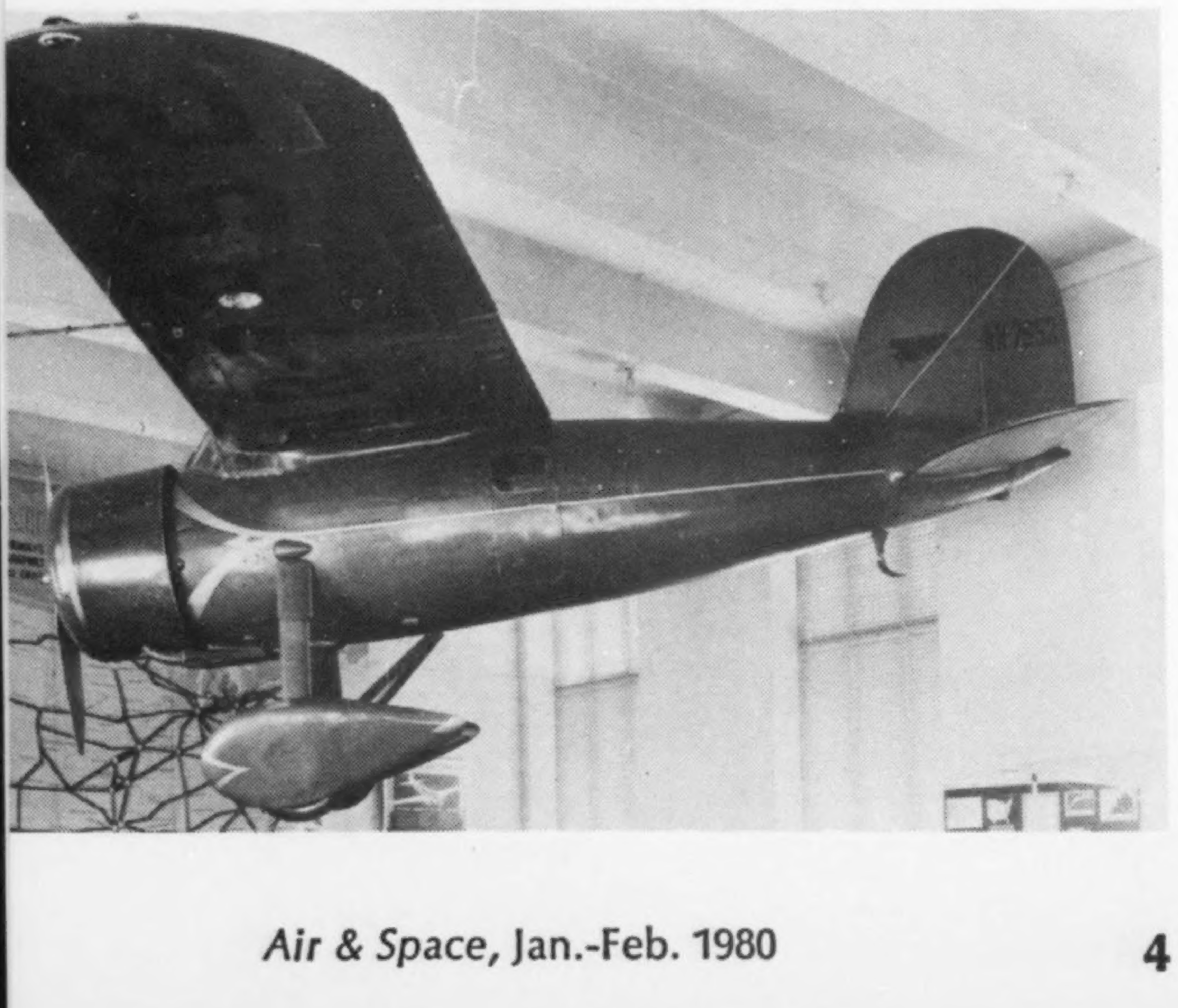
Lockheed Vega

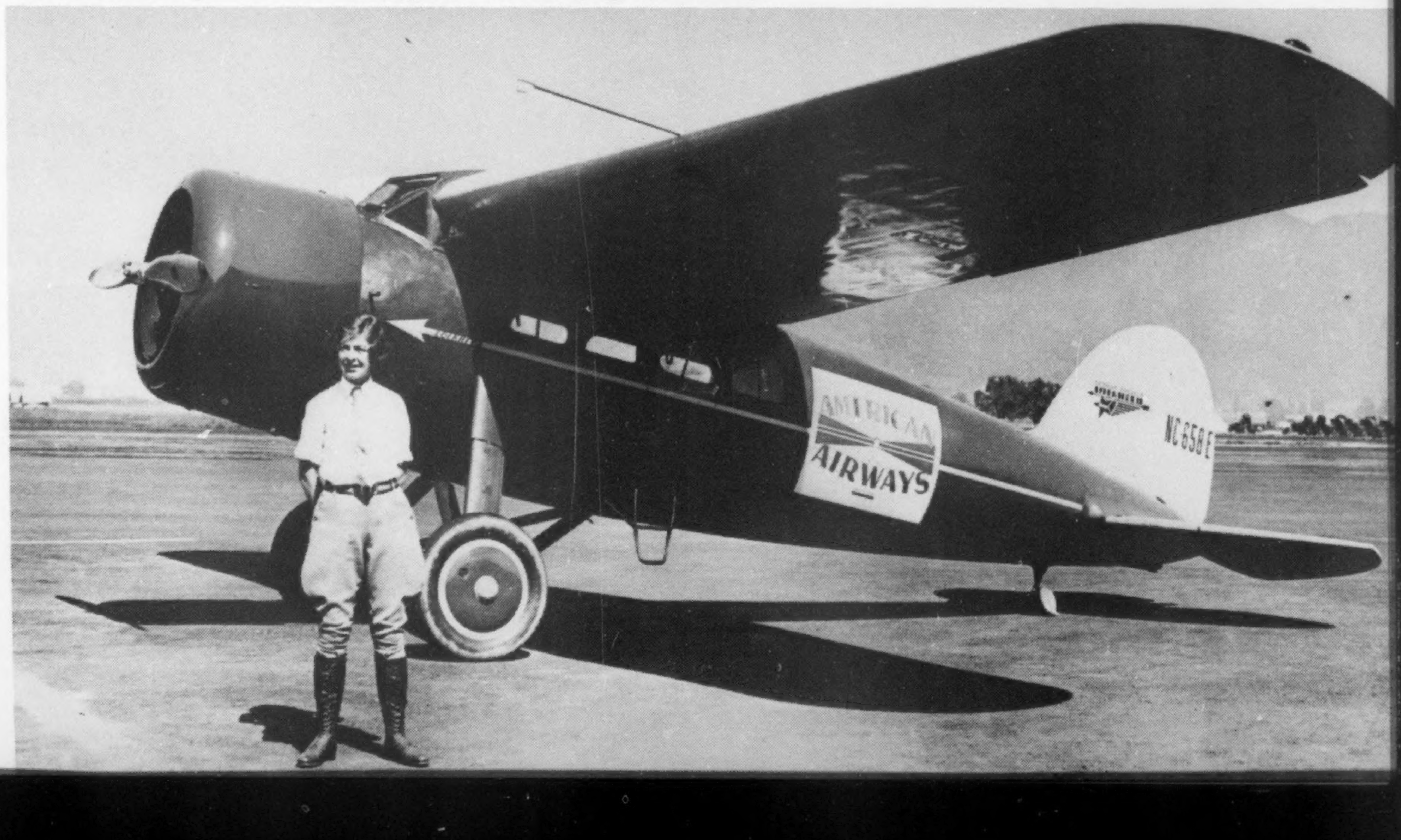
The Lockheed Vega first flew in 1927, reintroducing the monocoque fuselage shape that had first been used in the Deperdussin monocoque racing airplane of 1913. The monocoque fuselage is basically a shell that carries all or most of the flight stresses in its outer skin, maximizing both the load-carrying ability of the aircraft and its useful space. Semi-monocoque fuselages became standard in subsequent transports.

The Vega's fully-cantilevered wing and landing gear fairings reduced drag, as did the airplane's NACA long-chord engine cowling. The NACA cowl redirected airflow over the engine so as to actually produce negative drag, or a forward pull on the airplane. (Visitors to the National Air and Space Museum can demonstrate this principle to themselves in one of several working miniature wind tunnel displays located in the Flight Technology gallery.)

The NASM collection boasts two Vegas. Amelia Earhart's bright red Model 5B, in which she made the first nonstop solo flight across the Atlantic by a woman (May 20-21, 1932), reposes in the Pioneers of Flight gallery. The special Model 5C *Winnie Mae* used by Wiley Post in pioneering high-altitude research is displayed in the Flight Testing gallery. **28-35 pmpg**

Amelia Earhart's famous Lockheed 5B Vega (left, below) was similar to the standard model used by airlines during the 1930s (right, below).





Northrop Alpha

NASM's Northrop Alpha, built in November 1930, went to work for Transcontinental and Western Air, Inc., in late 1931. Like the Lockheed Vega, the 7-passenger Alpha utilized the NACA engine cowl, faired (streamlined) landing gear, and a semi-monocoque fuselage. But both the Alpha's fuselage and wings were made of aluminum. The Alpha's stressed-skin multi-cellular wing employed new structural techniques to obtain great strength from light weight. **36.0 pmpg**

NORTHROP AIRCRA
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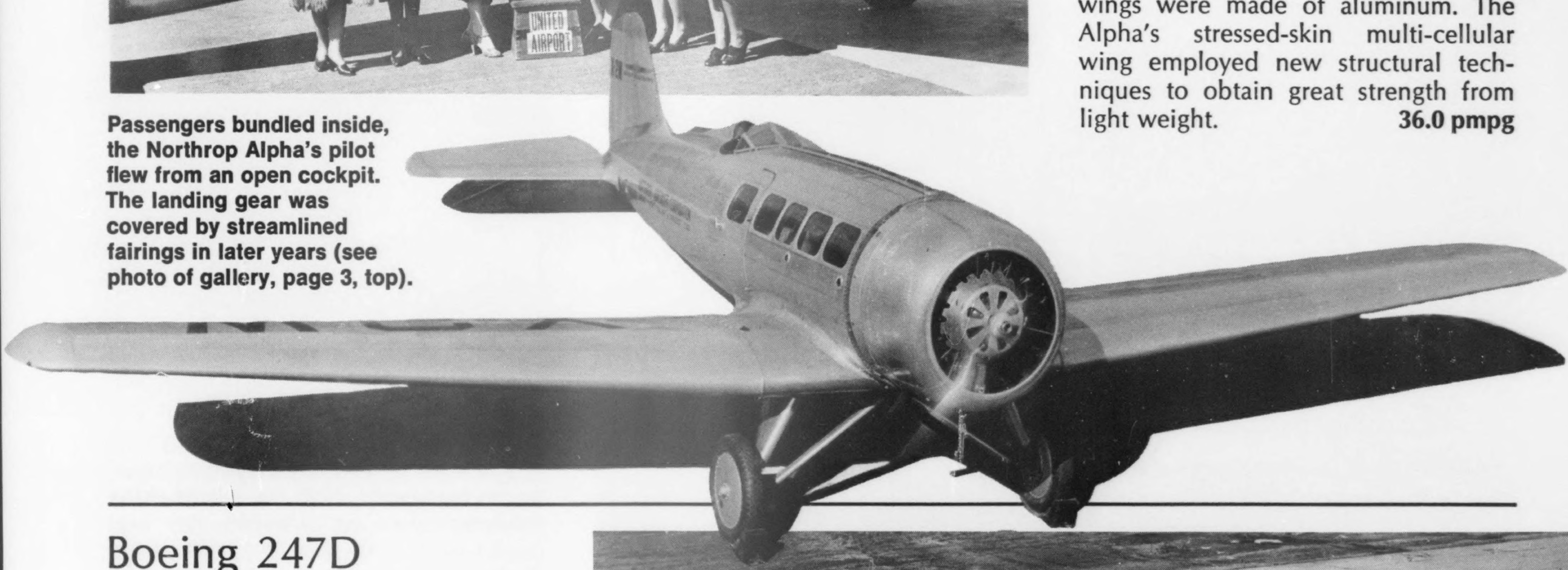
Passengers bundled inside, the Northrop Alpha's pilot flew from an open cockpit. The landing gear was covered by streamlined fairings in later years (see photo of gallery, page 3, top).



Boeing 247D

The first "modern" airliner, the 10-passenger Boeing 247 entered service on May 22, 1933. The engines of this all-metal, low-wing transport were mounted on streamlined nacelles projecting from the leading edge of the wing, producing less drag than underwing mounts like the Ford Tri-motor's. The 247 featured drag-reducing retractable landing gear; later models, like NASM's D model, had controllable-pitch propellers to more efficiently convert engine power to propeller thrust. **24.2-29.6 pmpg**

NC13369
NC 13369 BOEING
UNITED AIR LINES

NASM's Boeing 247D placed third in the 1934 London-to-Melbourne Race before going to work for United Air Lines.

Douglas DC-3

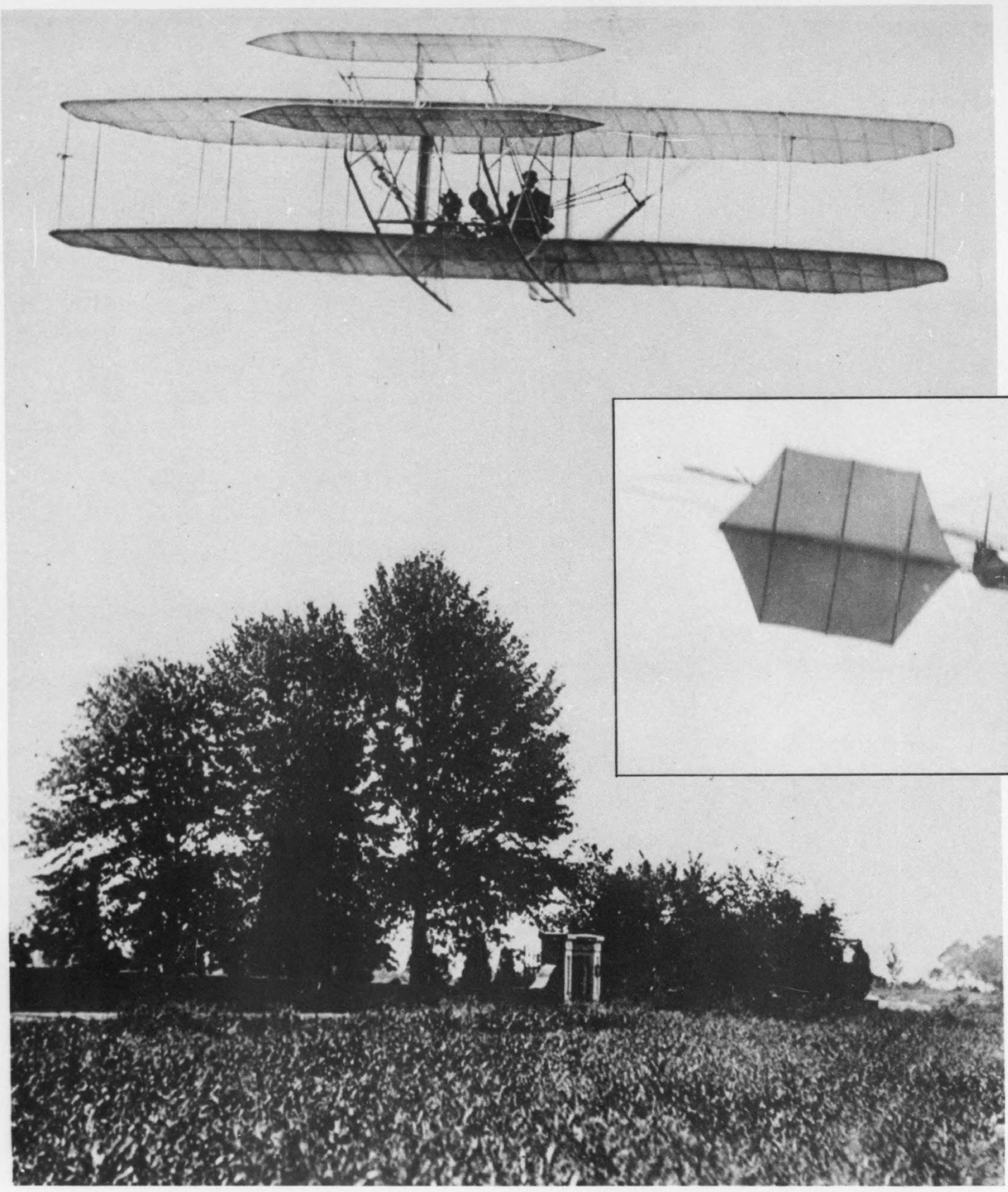
The Douglas DC-3, perhaps the single most important aircraft in the history of air transportation, somewhat resembled the Boeing 247. However, the DC-3 was aerodynamically "cleaner" (produced less drag per unit of lift) than the Boeing airliner, and could carry 21 passengers, while the Boeing had seats for only 10. The DC-3, the day plane version of the DC-2 Douglas Day Sleeper Transport (DST), entered airline service in September 1936; by 1938, about 80 percent of all U.S. airline traffic traveled on DC-3s. The DC-3 was, said American Airlines President C. R. Smith in 1937, "the first airplane in the world that could make money just by hauling passengers." **38.0-40.0 pmpg**

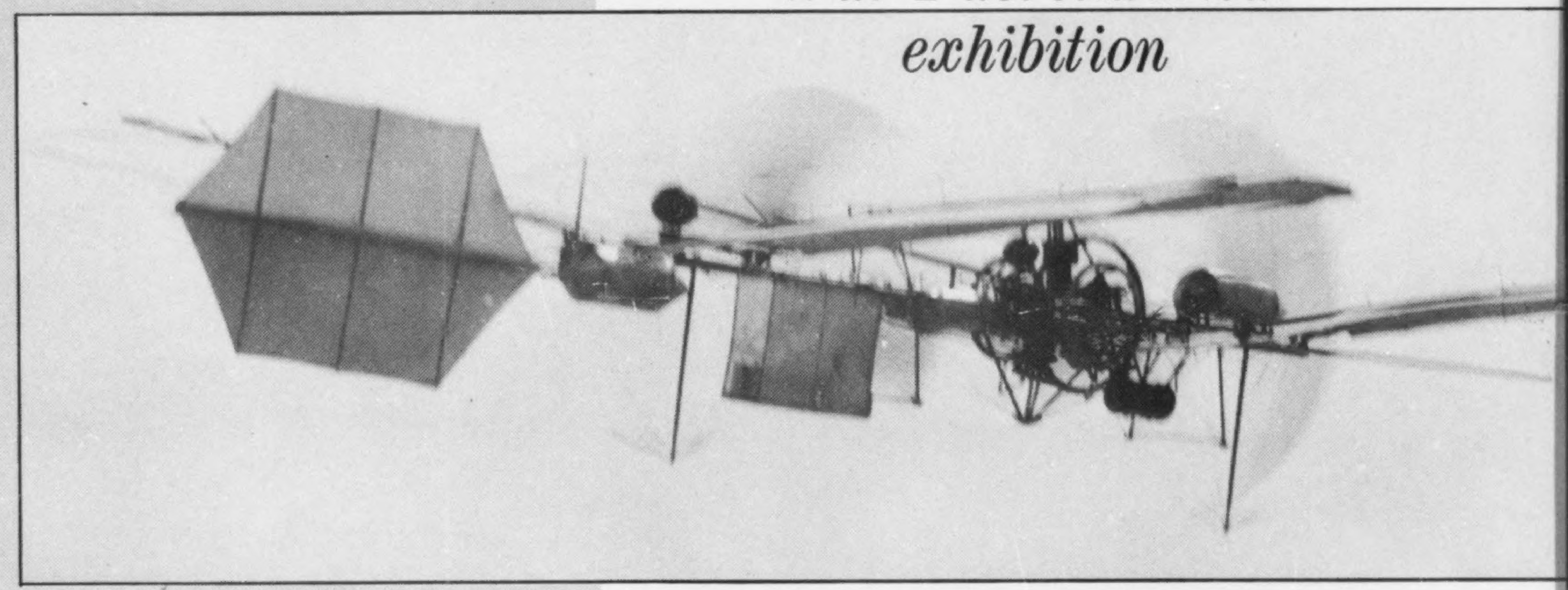
NC16088
UNITED

In service since 1936, the Douglas DC-3 is still in use today throughout the world.

Early Flight

A new Museum gallery recreates a pre-World War I aeronautical exhibition





Left: Orville Wright demonstrated this Wright Flyer to the U.S. Army at Ft. Myer, Va., in September, 1908. On July 30 of the following year, he satisfied the final requirement and won the first Army contract for an airplane, to be used by the Signal Corps. Above: The quarter-scale Langley Aerodrome, the first heavier-than-air craft to fly with an internal combustion engine, in flight over the Potomac River. Both aircraft will be exhibited in NASM's Early Flight gallery.

by Tom D. Crouch, Curator
Department of Aeronautics, NASM

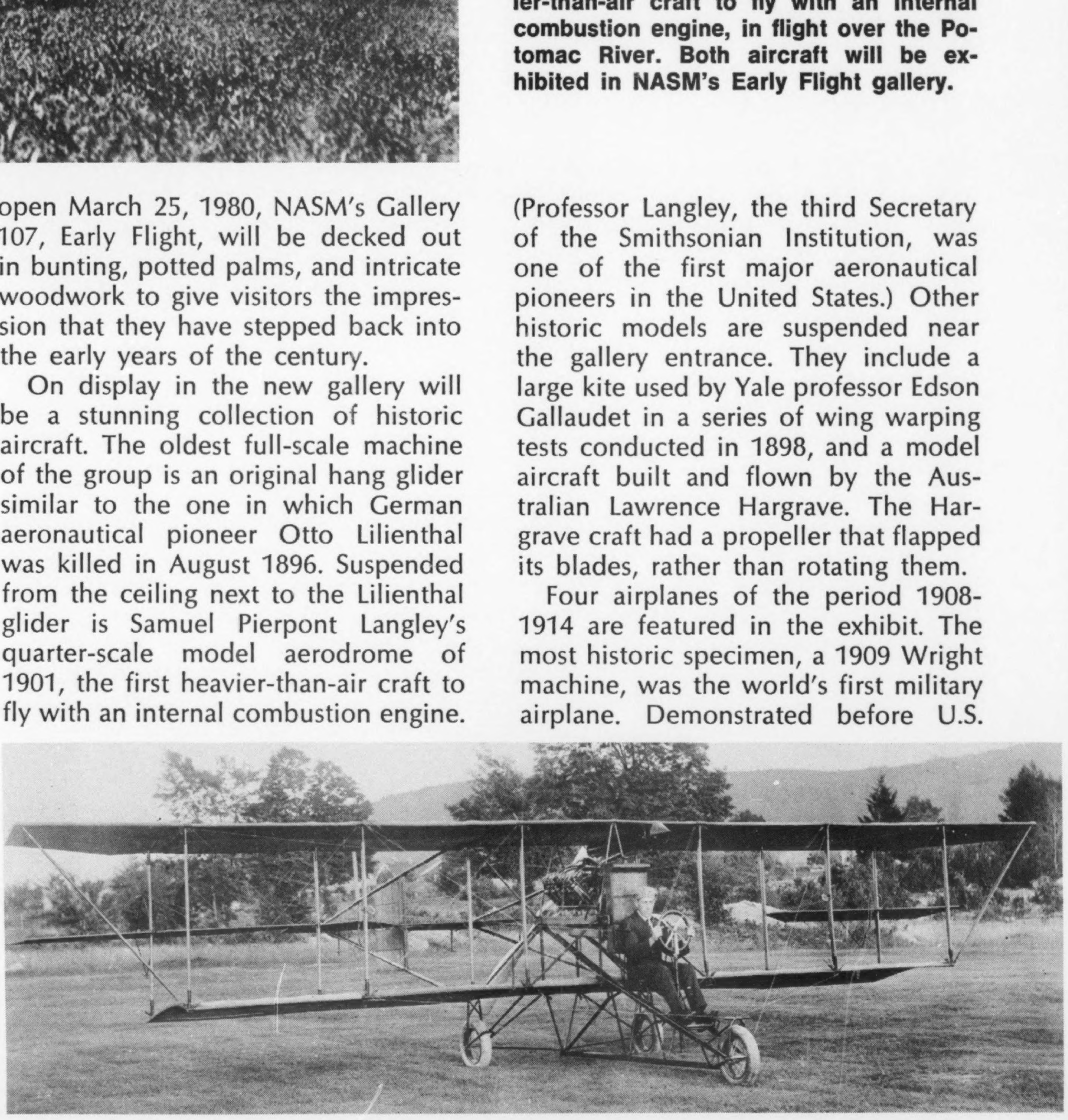
For Americans living in the first decade of the 20th Century, the airplane was something of a wonder. Spectators flocked to watch feats of aerial derring-do performed by celebrated stunt pilots like Lincoln Beachey, Ralph Johnstone, and Earl Ovington, and were treated to detailed accounts of aeronautical progress in newspapers and magazines.

Particularly exciting were the great indoor displays of the latest aircraft and aeronautical hardware held in large U.S. cities. Here, thousands of visitors could get their first close look at these marvelous flying machines and perhaps even have an opportunity to talk with an aviator.

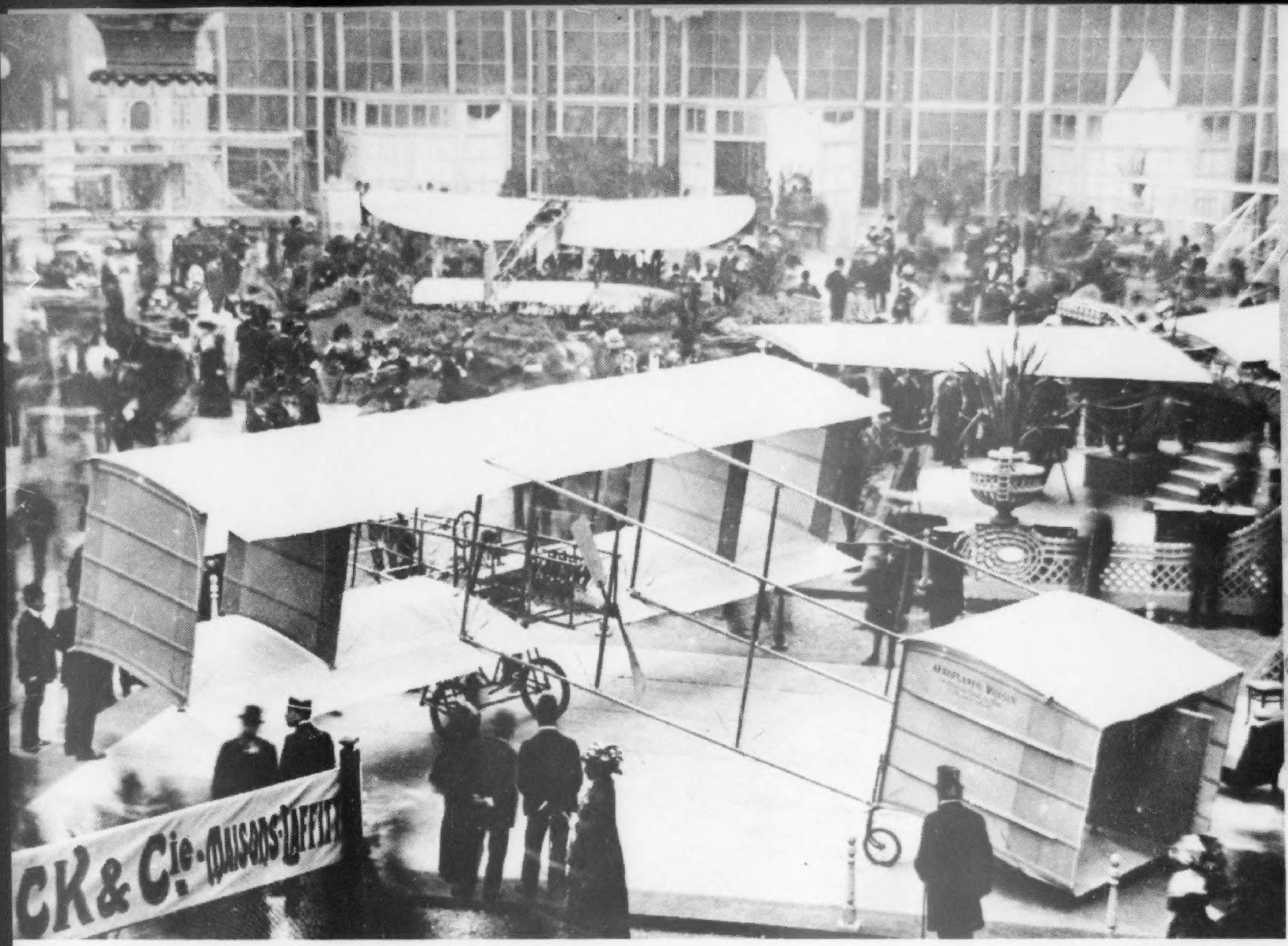
The National Air and Space Museum has recreated one of these pre-World War I aeronautical exhibitions to enable Museum visitors to recapture some of the color and excitement of the dawn of the air age. Scheduled to open March 25, 1980, NASM's Gallery 107, Early Flight, will be decked out in bunting, potted palms, and intricate woodwork to give visitors the impression that they have stepped back into the early years of the century.

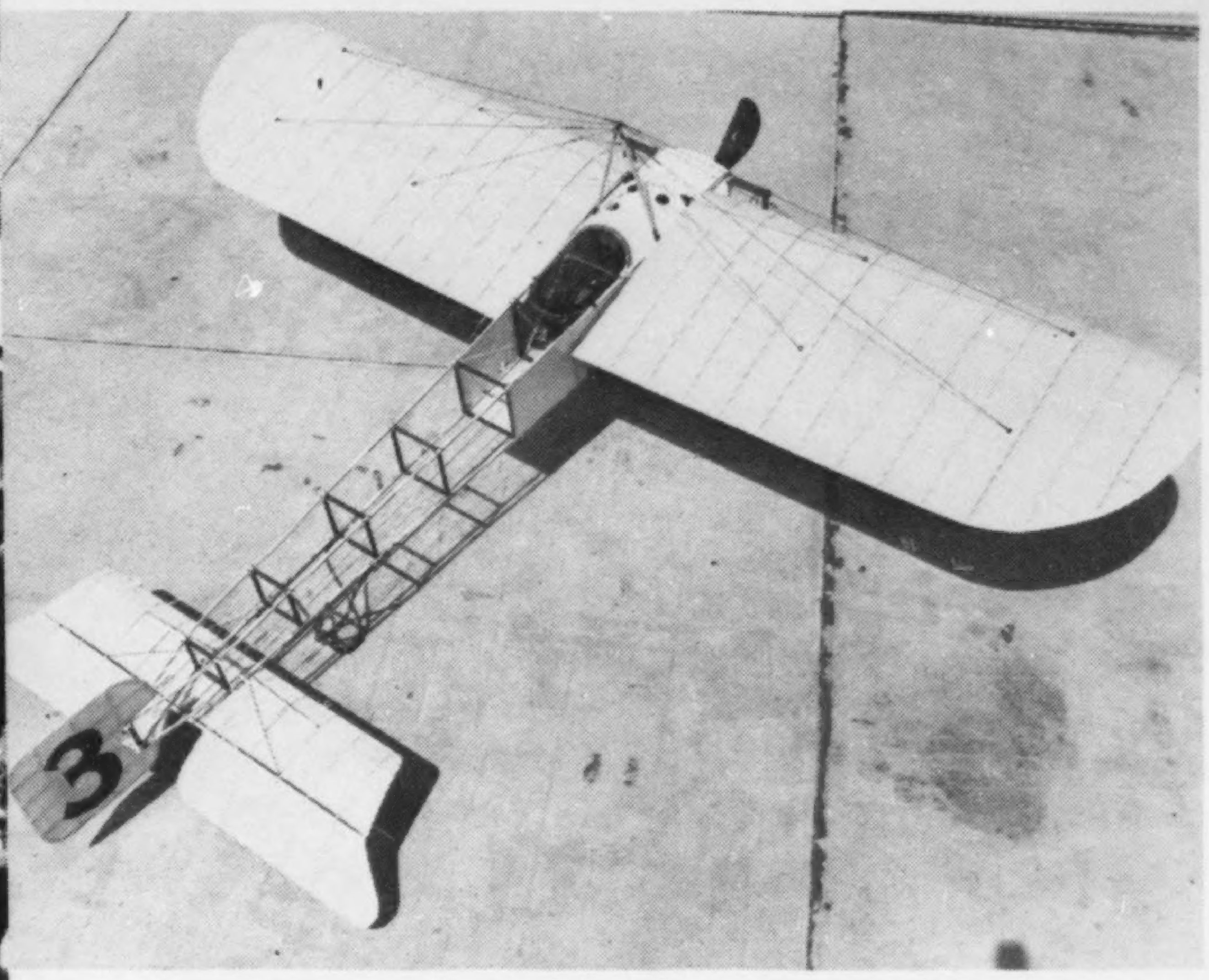
On display in the new gallery will be a stunning collection of historic aircraft. The oldest full-scale machine of the group is an original hang glider similar to the one in which German aeronautical pioneer Otto Lilienthal was killed in August 1896. Suspended from the ceiling next to the Lilienthal glider is Samuel Pierpont Langley's quarter-scale model aerodrome of 1901, the first heavier-than-air craft to fly with an internal combustion engine. (Professor Langley, the third Secretary of the Smithsonian Institution, was one of the first major aeronautical pioneers in the United States.) Other historic models are suspended near the gallery entrance. They include a large kite used by Yale professor Edson Gallaudet in a series of wing warping tests conducted in 1898, and a model aircraft built and flown by the Australian Lawrence Hargrave. The Hargrave craft had a propeller that flapped its blades, rather than rotating them.

Four airplanes of the period 1908-1914 are featured in the exhibit. The most historic specimen, a 1909 Wright machine, was the world's first military airplane. Demonstrated before U.S.



NASM's Curtiss D Headless Pusher is similar to this D III model, but lacks the upper wing extensions shown here.





Left: This early aeronautical exhibition featured Voisin (foreground) and Blériot (rear, center) aircraft of the kind displayed in NASM's Early Flight gallery. Above: The Museum's restored 1914 Blériot XI.

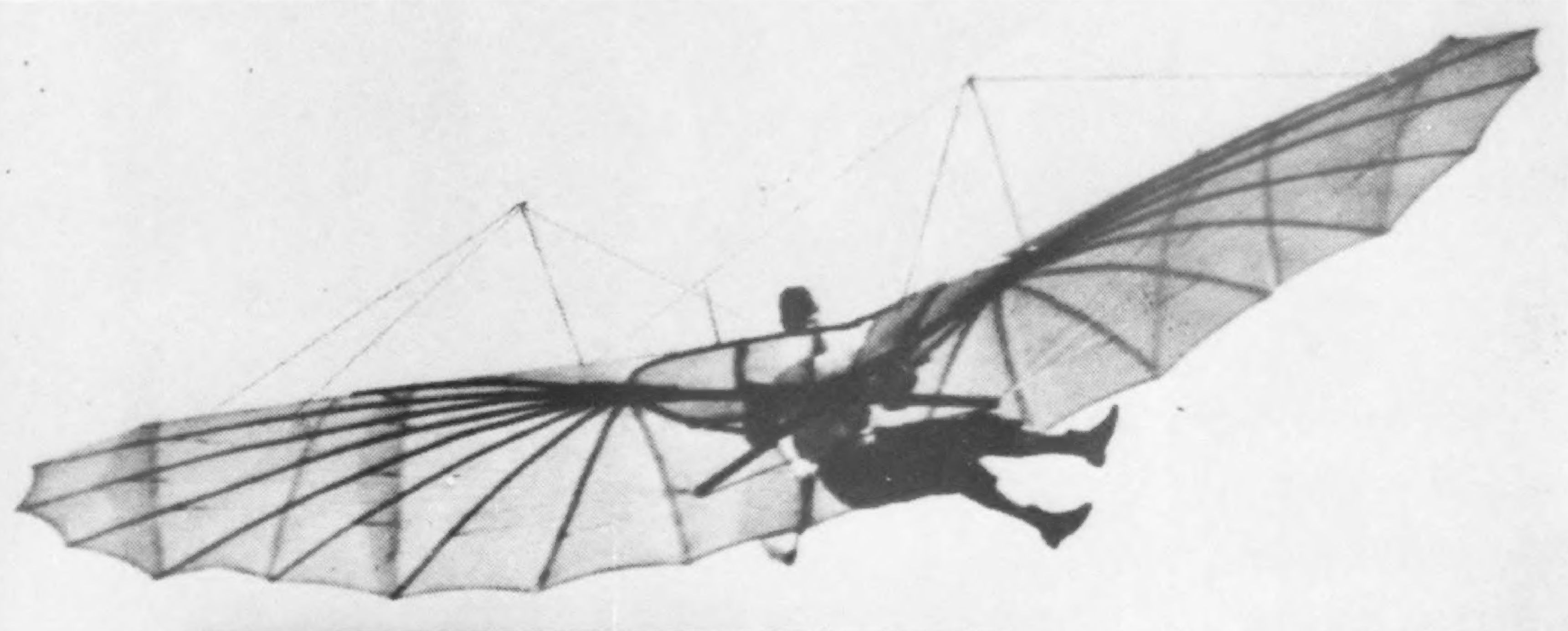
Army officials at Ft. Myer, Va., in 1909, the craft was flown extensively by Lt. Benjamin Foulois at Ft. Sam Houston, Tex. Later, it was returned to the Wright factory for refurbishment and presentation to the Smithsonian Institution in 1911.

A classic Voisin-type airplane, the type of craft in which so many first-generation European pilots earned their wings, is also on exhibit. Constructed by C. Norvin Rinek of Easton, Pa., in 1908-1909, it was based on French plans and includes original metal fittings imported from Paris. Powered by an engine also constructed by Rinek, his airplane, with its box kite-like wings and tail and spindly, pipeframe undercarriage and tail support, is a testament to the courage of the early aviators who flew it.

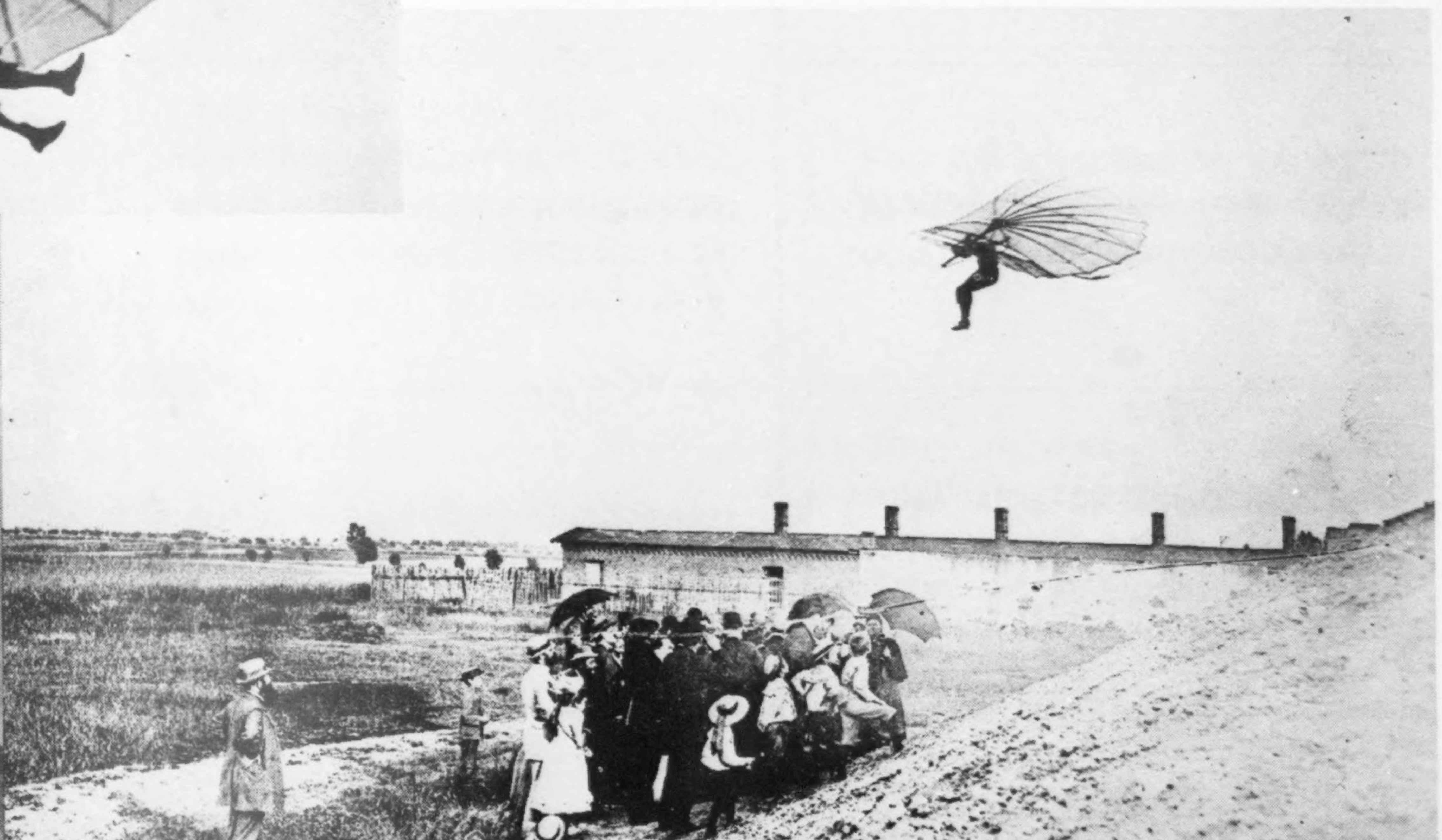
A 1911 Curtiss Headless Pusher, one of the most popular American airplanes of the period, hangs in a third corner of the gallery. Easily identified by their distinctive mid-wing ailerons and exposed pilot position, Curtiss Headless Pushers were flown by members of the Curtiss exhibition team and many of the independent barnstormers who crisscrossed the nation prior to World War I.

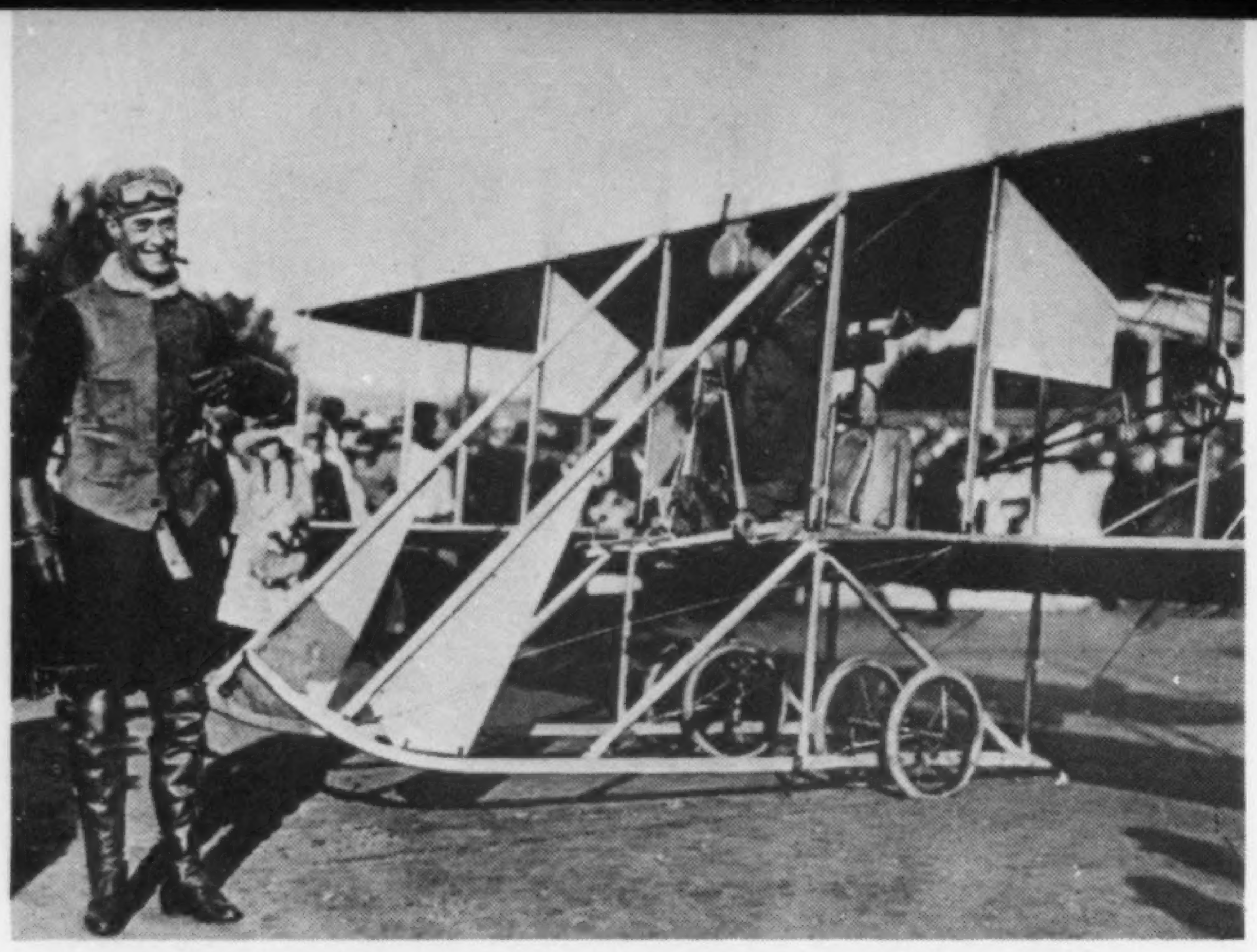
The final airplane on display is a beautifully-restored Blériot XI, similar to the one in which Louis Blériot made the first crossing of the English Channel by airplane on July 25, 1909. The Museum's Blériot was purchased by John Domenjoz, a Swiss aviator who earned a reputation as a particularly daring exhibition flier with this very machine.

In addition to the full-scale aircraft, an extensive collection of period engines, propellers, instruments, and items of flying clothing are featured in the Early Flight exhibition. Visitors to the gallery can also watch films of the pilots and planes of the pre-War epoch, and study displays ranging from the flying controls of the period to the role of women in early aeronautics. For visitors to the ever-popular National Air and Space Museum, then, early flight will be not just a period of history, but a gallery bustling with the aeronautical sights and sounds of 1913.



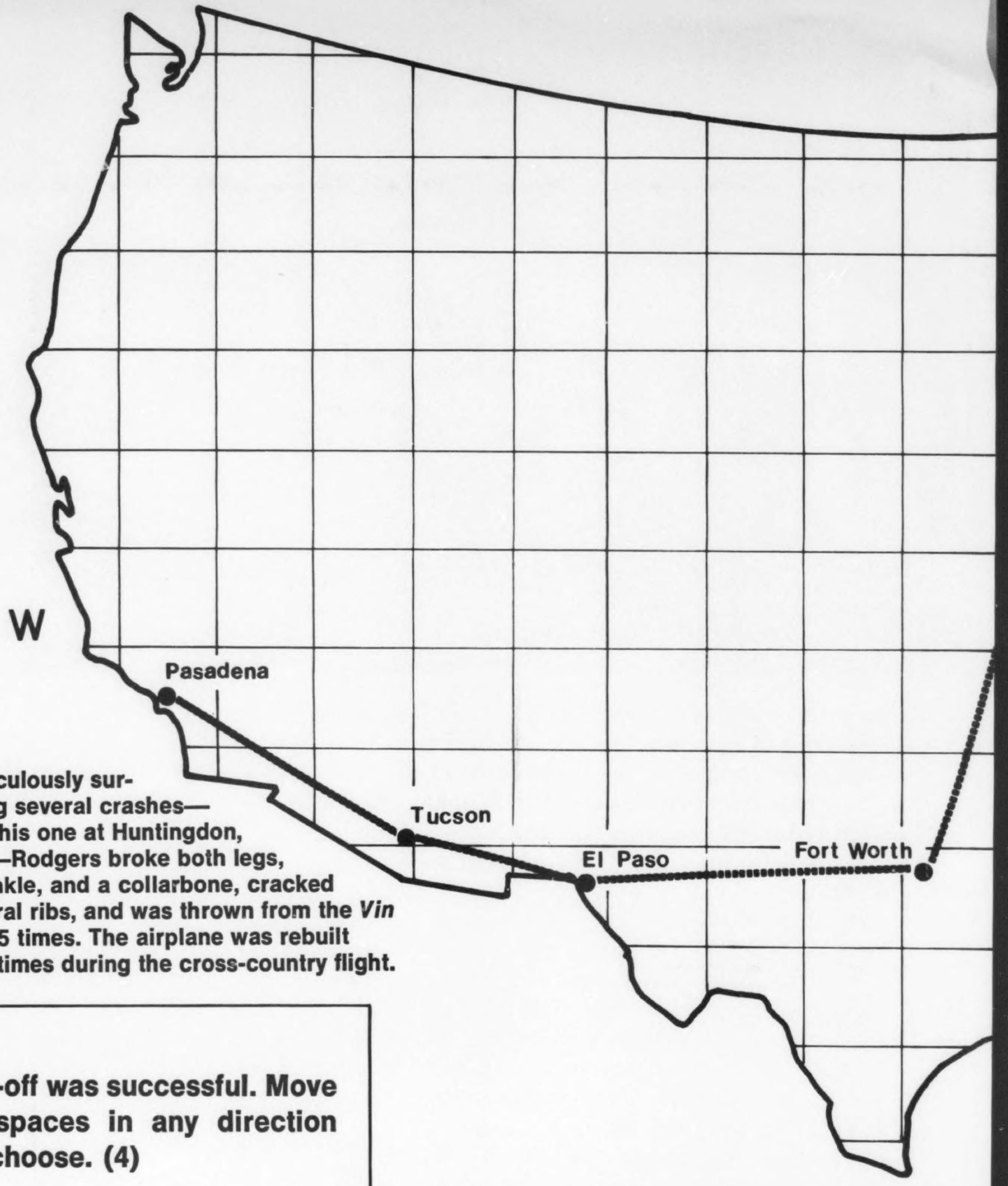
Otto Lilienthal (1848-1896), the most important of the pre-Wright aeronautical pioneers (left, below), applied his study of bird flight to the development of 18 different types of hang gliders, controlled primarily by the pilot shifting his weight (left). Lilienthal made many of his flights from an artificial hill constructed near his home in the Berlin suburb of Gross-Lichterfelde (below).





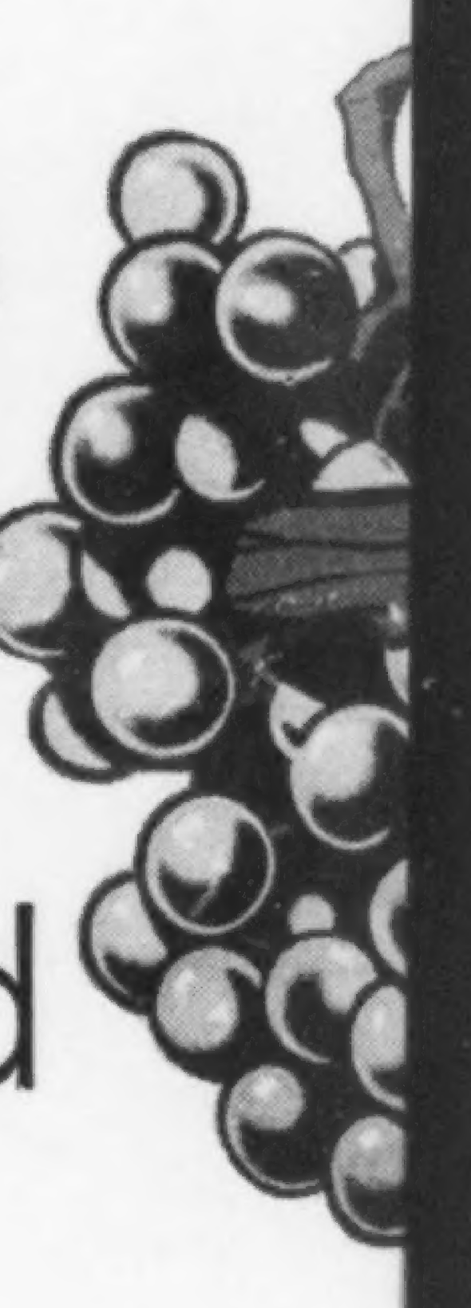
Newspapers jammed under his vest for extra warmth, Cal Rodgers enjoyed a seemingly ever-present cigar between flights. Here a mechanic makes last-minute adjustments to the *Vin Fiz.*

Miraculously surviving several crashes—like this one at Huntingdon, Ind.—Rodgers broke both legs, an ankle, and a collarbone, cracked several ribs, and was thrown from the *Vin Fiz* 15 times. The airplane was rebuilt four times during the cross-country flight.



Souvenir hunters damage your airplane. Lose one turn. (2)	Take-off was successful. Move two spaces in any direction you choose. (4)
You recognize a landmark along the railroad tracks. You know you are on course. Move one space in any direction you choose. (3)	Move to Kent, Ohio. (1)
There is no safe place to land. Move one space south. (2)	The J. Ogden Armour Company gives you a bonus. Move two spaces in any direction you choose. (4)
The winds are in your favor. Move two spaces in any direction you choose. (4)	Move to Fort Worth, Texas. (1)
You are injured when a connecting rod in your engine breaks in flight. Move one space east. (2)	Good weather. Move one space in any direction you choose. (4)

VIN

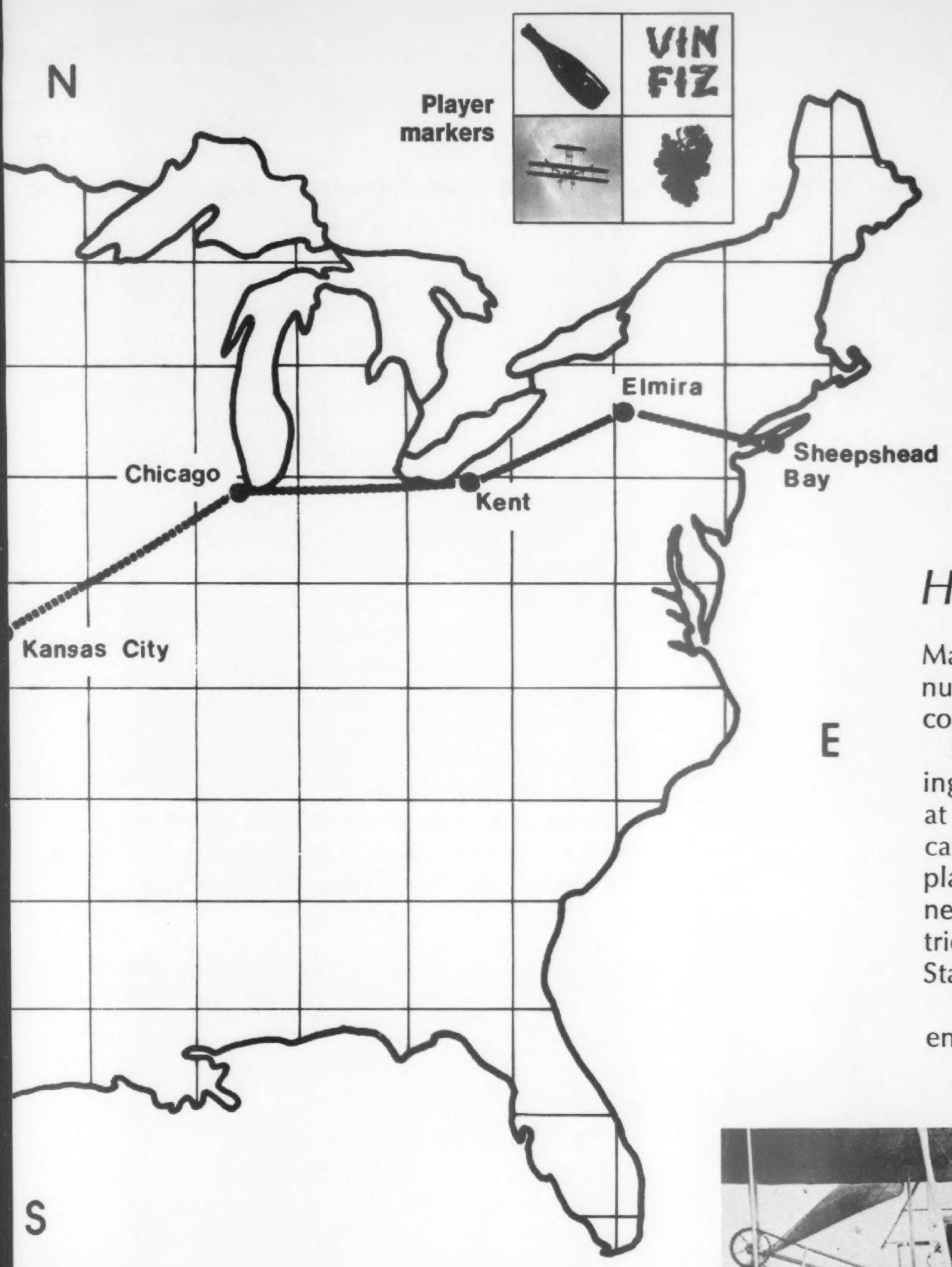


Board

by Janet K. Wolfe
Unit Chief, Outreach Programs
Education Services Division, NASM

Few men have met and conquered the obstacles that Calbraith Perry Rodgers faced in accepting the challenge of a coast-to-coast flight across the United States in 1911—fewer than 8 years after the Wright brothers made the first successful flights in an airplane.

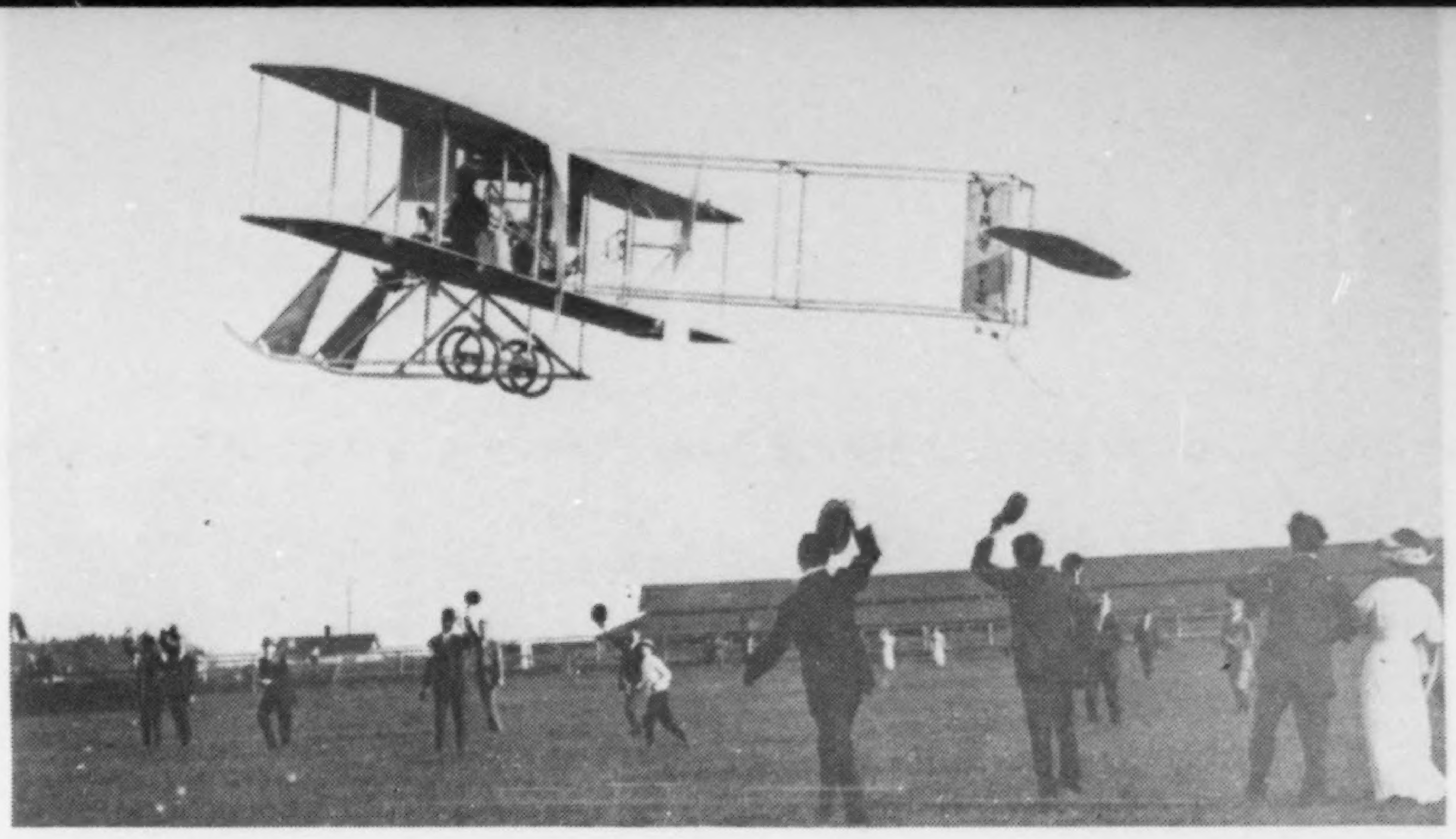
William Randolph Hearst, publisher of the Los Angeles *Examiner*, offered a $50,000 prize to the first pilot to cross North America by air in 30 days. "Cal" Rodgers planned to compete for the prize by flying a Wright EX biplane. He received financial support for airplane parts, fuel, mechanics, a special



FIZ Game

railroad train, and other expenses from the J. Ogden Armour Company. In return for this financial support, Rodgers agreed to advertise the Armour Company's Vin Fiz grape soda drink. He painted the Vin Fiz name on the tail and wings of his airplane.

Rodgers took off from Sheepshead Bay, Long Island, N.Y., on September 17, 1911. Because of numerous crashes and other delays, his transcontinental flight to Pasadena, Calif., took 49 days, too long to win the Hearst prize. Nevertheless, Rodgers did become the first to fly across the continent, reaching Pasadena on November 5, 1911. Today the restored *Vin Fiz* hangs in the Pioneers of Flight gallery at the National Air and Space Museum.



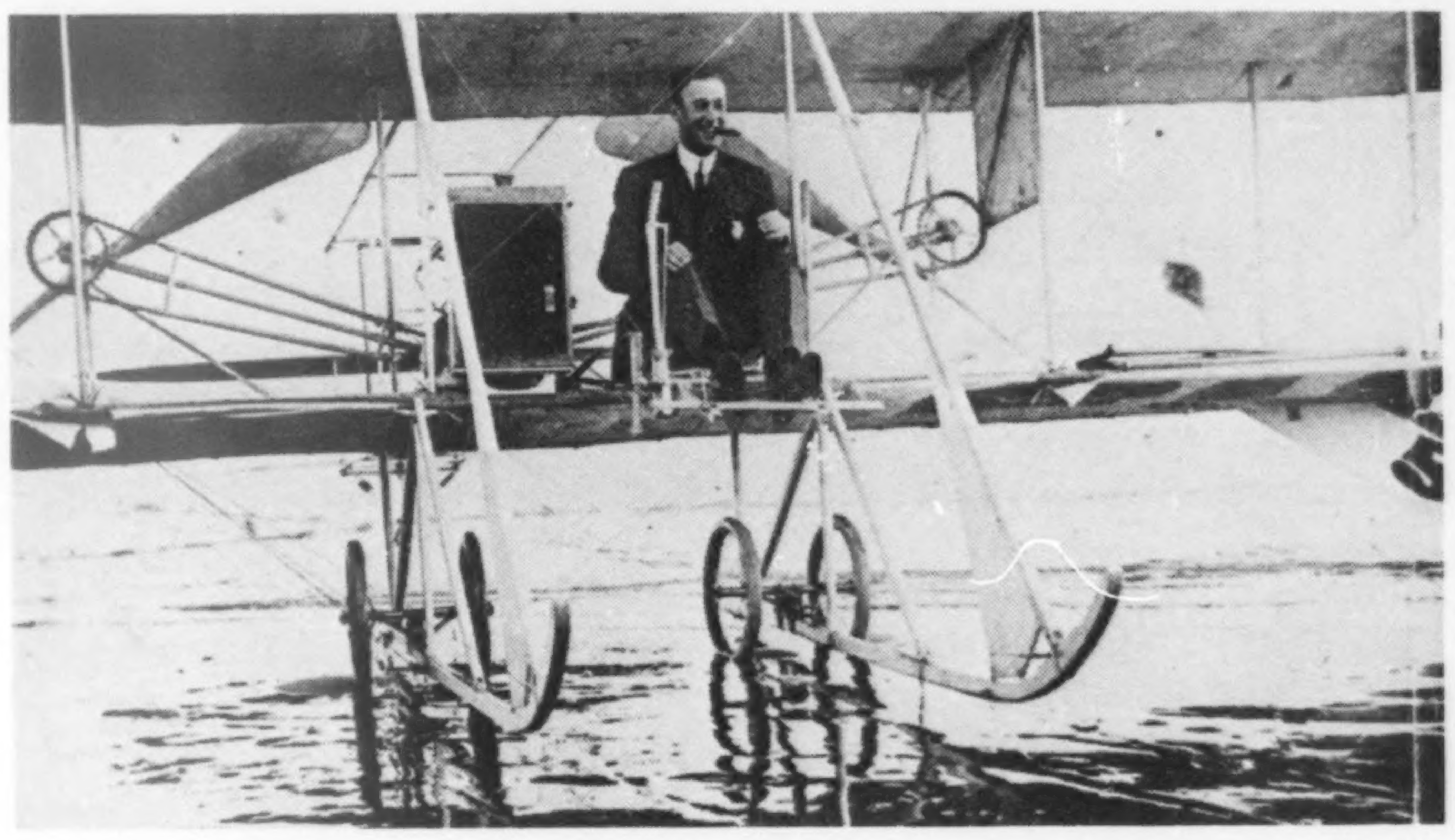
Well-wishers cheered Cal Rodgers as he lifted off from a grassy field in Sheepshead Bay, Long Island, on September 17, 1911.

How to Play the Game

Make photocopies of the flying cards and player markers. The number in parentheses on each flying card tells how many copies of that card to make.

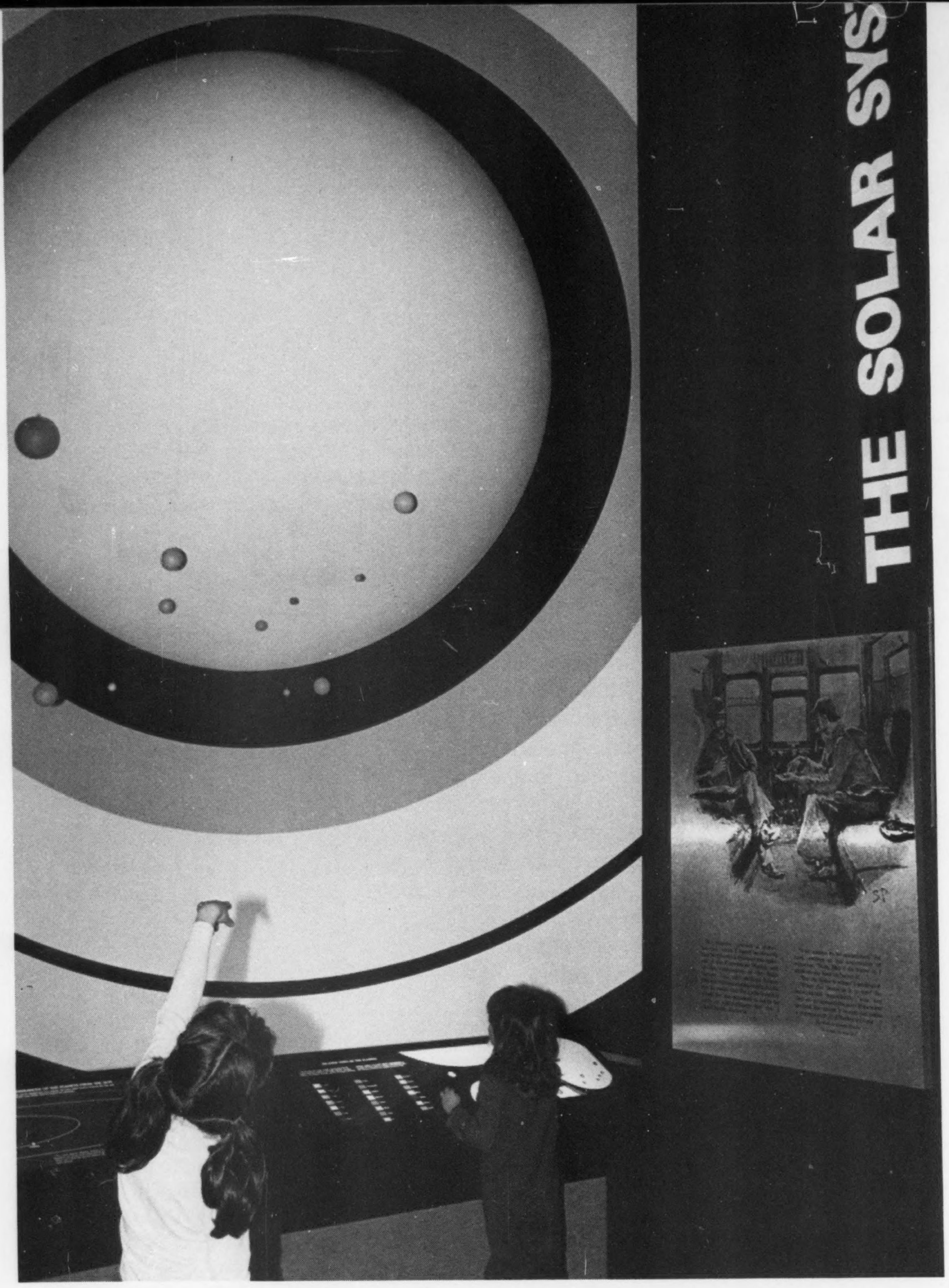
Shuffle the flying cards. Place them face down on the playing surface. Two to four players can play. Each player begins at Sheepshead Bay. At each turn, the player selects a flying card and moves according to the directions on the card. Each player tries to arrive at Pasadena before the others. It is not necessary to try to follow the railroad tracks as Cal Rodgers tried to do. Keep markers inside the continental United States.

The game ends when a player reaches Pasadena, or at the end of 30 minutes.



Cal Rodgers felt his transcontinental trip would not be complete until he actually flew to the Pacific Ocean. On December 10, 1911, he taxied the *Vin Fiz* into the ocean off Long Beach, Calif. Note the crutches lashed to the top of his lower left wing; Rodgers was still recovering from a recent crash.

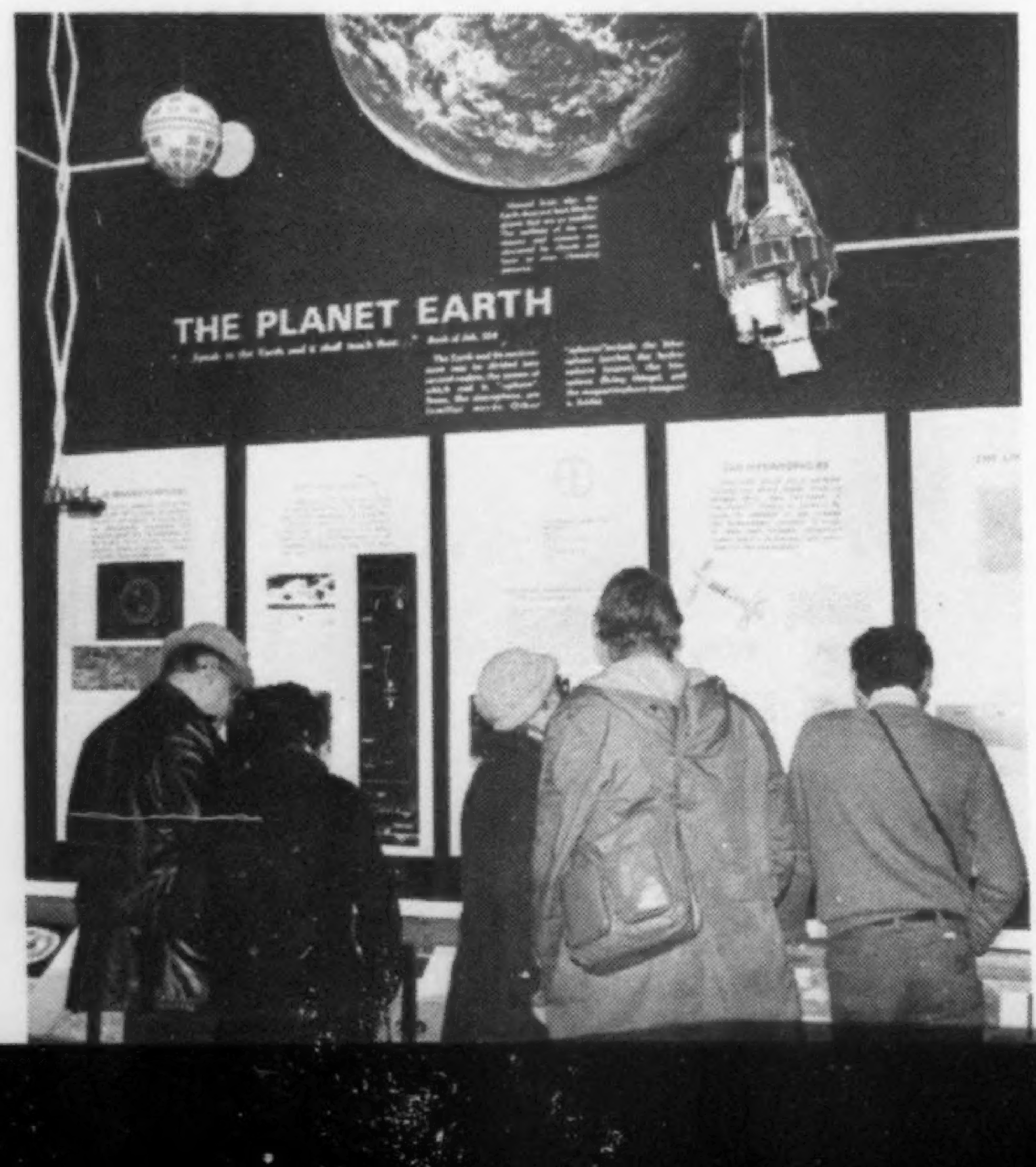
Your train with spare parts meets you near your landing spot—on time! Move one space in any direction you choose. (4)	**You are attacked by an eagle in flight. Move one space north. (2)**
Move to Kansas City, Missouri. (1)	**You receive no advance weather reports. You are caught in the storm and must delay your flight. Lose one turn. (3)**
You crashed on landing. You need a new wing and landing skids. Lose one turn. (3)	**You are following the wrong railroad tracks. Move one space east. (2)**



"My surprise reached a climax . . . when I found . . . [Sherlock Holmes] was ignorant of . . . the composition of the Solar System," lamented Dr. Watson in Sir Arthur Conan Doyle's "A Study in Scarlet." "What the deuce is it to me?" replied Holmes. "You say that we go around the sun. If we went around the moon it would not make a pennysworth of difference to me." Unlike Holmes, young Museum-goers become excited about models showing the relative sizes of the planets and their moons.

Creating a New Gallery at the National Air and Space Museum

by Melvin B. Zisfein
Deputy Director, NASM



No tour of the Solar System would be complete without a stop at Earth, the only planet known to support life. Home takes on a new look when studied from space like the other planets.

The major attraction of the National Air and Space Museum is its 23 exhibit galleries, which occupy about 23,000 square meters (250,000 square feet) of floor space. Our goal has been to use this space for the presentation of the history, science, and technology of flight in all its aspects.

The National Air and Space Museum's basic creed is to communicate with the visitor in such a pleasurable fashion that he or she has a totally enjoyable experience while assimilating a great deal of useful and interesting information. To effect this kind of communication, we employ methods as simple as labeled artifacts and as complicated as elaborately programmed audiovisual shows.

As a group, we are enthusiastic about our subject matter, and some of our most pleasurable work experiences occur when we sit down to solve a problem. Naturally, some of our most agonizing experiences occur before we come up with the solution.

We believe strongly that we are not a propaganda device and that we must be faithful to the truth, usually presented as observable facts. Sometimes (particularly when dealing with the future or unknown) we do present conjecture of the "best guess" variety, but we clearly label it as such.

We go through an elaborate planning process to decide which exhibit galleries to close and which new ones to open. One result of this process was the recent replacement of our Air Traffic Control gallery with a new gallery entitled "Exploring the Planets."

The concept of the Exploring the Planets gallery was to take the visitor on a time and space journey through the history, science, and technology of the exploration of our Solar System. We began with a series of concept development meetings in which we developed a number of educational goals for the gallery and the manner in which these were to be communicated. These meetings led to a concept script which I co-authored with Dr. Robert W. Wolfe, a geologist in NASM's Center for Earth and Planetary Studies. Bob was assigned curatorial responsibility for the job.

In the concept stage we postulated some grandiose new audiovisual shows for some parts of the gallery; other sections called for simply labeled artifacts. In one or two places we attempted the creation of special effects never before developed.

Let me take you on a tour of the gallery. As we enter, we see a conventional exhibit unit devoted to the work of the first explorers of our Solar System, the early astronomers. Beginning with cuneiform inscriptions on a Babylonian clay tablet that recorded astronomical calculations in the 1st Century B.C., we proceed through the achievements and artifacts of various astronomers. We finish by showing one of the two actual glass photographic plates from which the planet Pluto was discovered, and the excited handwriting

Its magnetometer boom outthrust inquisitively from behind its 3.7-meter (12-foot) diameter dish antenna, a replica of the Voyagers reaches into the shadows above the Exploring the Planets gallery. Voyagers 1 and 2 are hurtling towards Saturn fly-bys in 1980 and 1981 respectively.

"Which planet has the most satellites (moons)? A. Jupiter B. Saturn C. Uranus D. Neptune." Visitors to NASM's Exploring the Planets gallery can test their knowledge of the planets and mankind's exploration of them by taking a computerized Space Academy Exam. Five multiple-choice quizzes cover Simple Facts, Spacecraft Firsts, The Red Planet, The Third Planet, and Gas Giants.

of astronomer James L. Elliott on a piece of paper. (Elliott, while aboard the Kuiper Airborne Observatory, discovered "small bodies"—actually rings —near Uranus. The paper was the original draft of a message he sent to the editor of *Astronomical Telegrams*.)

We next take the visitor into an area that shows the various tools of exploration, ranging from earthbound optical and radio telescopes to airborne and satellite telescopes and other observation devices, plus the tools of manned planetary exploration. My favorite object here is the large photomontage globe of Mars made from Mariner 9 photographs. I am particularly fascinated by this globe because it answered many of the early questions about Mars (such as "Does it have canals?"), and in the process raised many new questions. Exploration has a way of doing that!

Continuing into the gallery we find, artfully presented, a number of facts about the planets and their satellites, ranging from their relative sizes to the wealth of surface detail we now know.

In the area devoted to Venus, we take a visitor several hundred years into the future, when space travel might be sufficiently commonplace that adventurous sightseers could take a trip to the surface of that planet. Visitors enter a spaceship-like chamber; on television monitors they witness their approach to Venus, their entry into the Venusian atmosphere, and their descent to the surface. The trip is narrated by the chief pilot. Occasionally she communicates with a talking computer named by my associates the Mission Electronic Lander, better known by its acronym, MEL. The correlation of this acronym with my nickname is a bit of an inside joke.

Another special unit in our Exploring the Planets gallery features some large and painstakingly sculptured rotating drums that the visitor can see only through special optical ports. The optical effect is to present to the visitor a three-dimensional view that he or she might see of Mars while in a low orbit over this planet.

As we move through the Exploring the Planets gallery, we progress through the asteroid belt toward the outer planets. One asteroid that we show has the form of a very large peanut, a shape that fascinated President Carter when I escorted him through this gallery.

Moving toward the outer planets, we encounter a show, "For Space Juniors," in which, on a simulated spaceship screen, young people can see the planets whizzing by them as they hear "The Planets of the Sun." This "masterpiece," created by Bob Wolfe and me over lunch one day, is sung to the tune of "The Farmer in the Dell" (see March-April 1979 *Air & Space*, page 15).

Our next units deal with the outer planets. Information gained from the recent Voyager and Pioneer spacecraft encounters with Jupiter and Saturn makes a major update of this gallery a near-future necessity, although it is just over one year old.

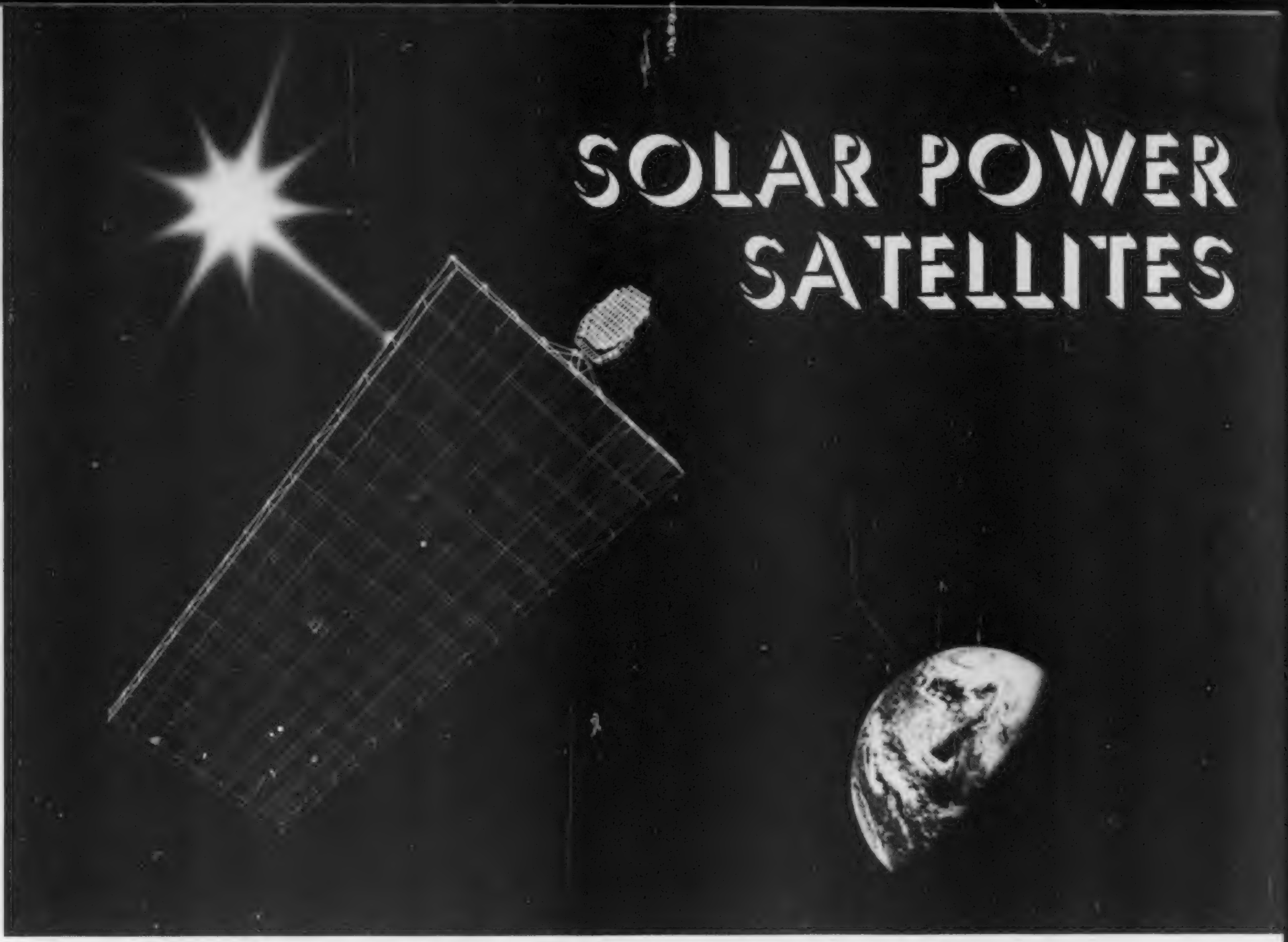
The gallery concludes with a series of exhibit units on comparative planetology, encompassing such subjects as volcanism, meteorology, planet interiors, and cratering. As we leave, we see a wall unit flashing a series of currently unanswered questions that are particularly stimulating and might serve as good class discussion questions:

1. Is there life in the clouds of Jupiter?
2. Are Mars' moons captured asteroids?
3. Why does Venus rotate "backwards"?
4. Are the rings of Saturn ice or pieces of rock covered by ice?

In a mini-theater "For Space Juniors," rapt families of humans learn about the Family of the Sun (the planets).

SOLAR POWER SATELLITES

by Gregory P. Kennedy
Assistant Curator
Department of Space Science and Exploration, NASM



In this artist's conception, a future Solar Power Satellite weighing 220 million kilograms and covering 50 square kilometers beams microwave energy to a receiving station on Earth, providing 5000 megawatts of electricity to a commercial power grid.

Energy for industrial growth during the first four fifths of the 20th Century has come largely from petroleum products. During that period, oil and natural gas were cheap and abundant, so the industrialized nations became dependent on fossil fuels. However, the world's supplies of such fuels are finite, and the end may be in sight. This realization, and increases in oil prices, have prompted growing consideration of alternative energy sources.

The Solar Power Satellite (SPS) is one of the energy alternatives under study. The SPS would collect energy from the Sun in space for transmission to the Earth's surface. This concept was proposed by Dr. Peter Glaser in an article entitled "Power from the Sun: Its Future" in the November 22, 1968 issue of *Science*. Dr. Glaser described a plan by which an orbiting satellite would be used to collect solar energy to generate electricity. The electrical energy would be transmitted to a receiving station on Earth via microwaves.

One of the reasons that Dr. Glaser's article initially failed to attract greater attention was the high cost of placing payloads in orbit in 1968. Soon the Space Shuttle will be able to place payloads in Low Earth Orbits (LEO's) of up to 960 kilometers (600 miles) altitude at lower costs than expendable space launch vehicles. With its 4.6- by 18.3-meter (15- by 60-foot) payload bay and a payload capacity of 29,500 kilograms (65,000 pounds), the Space Shuttle will replace the family of expendable launch vehicles now in service. The first test flights of the Shuttle are scheduled for later this year, and it is expected to enter operational service in 1981. This may remove one of the economic stumbling blocks to serious consideration of SPS development.

During 1974-75, NASA examined the technological and economic considerations of the SPS concept in a series of studies directed toward long-range future options. These studies concluded that the SPS is possible using existing technology. However, it would be a major long-range space program.

One requirement would be the development of a Heavy Lift Launch Vehicle (HLLV) or space "freighter" with a payload capacity of 200-500 metric tons (220-550 U.S. tons). This type of vehicle could reduce the cost of launching payloads to LEO to less than one-fourth that of the Shuttle.

The SPS would be in orbit 35,900 kilometers (22,300 miles) above the Earth's equator. At that altitude, it takes an object 24 hours to complete one orbit. Thus the SPS would remain fixed in the sky relative to the rotating Earth. This type of orbit is called Geosynchronous Earth Orbit, or GEO. Space tugs or auxiliary propulsion units would transfer the SPS components from LEO to GEO.

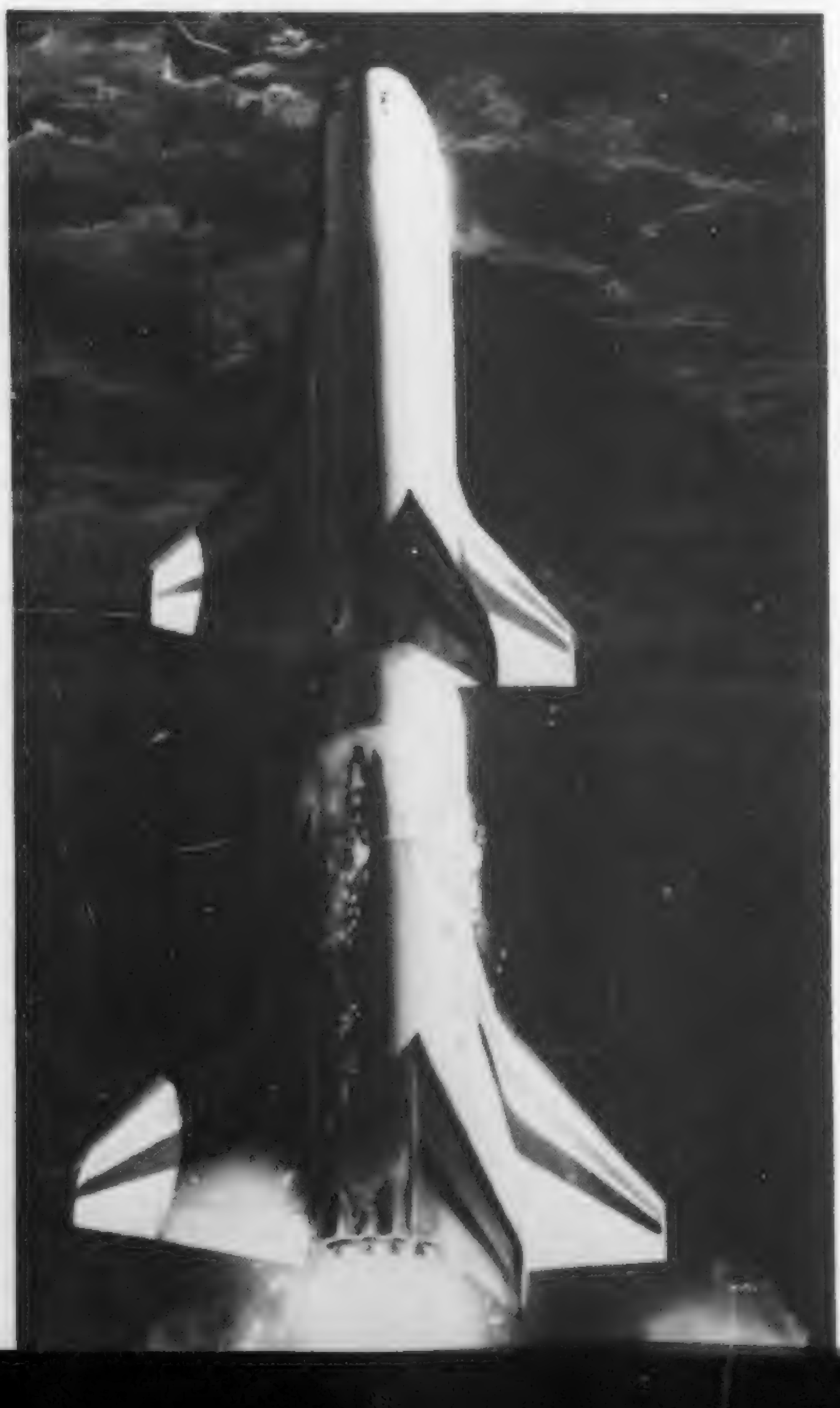
Two types of systems are under consideration for SPS power conversion: the photovoltaic cell and the thermal engine.

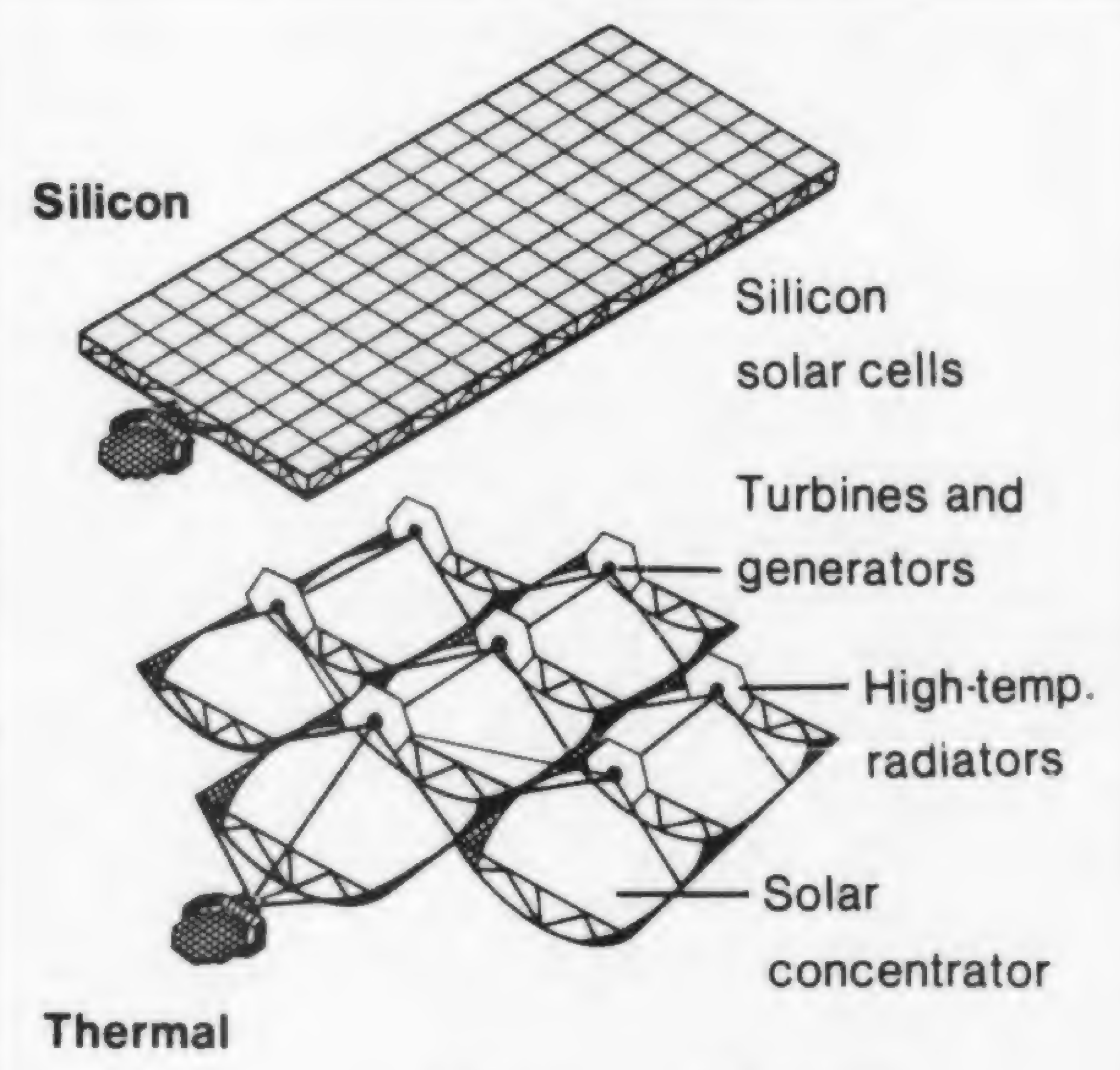
Photovoltaic cells, popularly known as solar cells, utilize the Sun's radiant energy directly to generate electricity. Thermal engines, on the other hand, concentrate the Sun's rays to heat a working fluid that is used to drive a generator.

Solar cells have had their greatest application in the space program. Vanguard 1, launched on March 17, 1958, was the first satellite to use this form of power generation. (A replica of Vanguard 1 is on display in NASM's Satellites gallery.) Today, nearly all Earth-orbiting unmanned spacecraft use solar cells.

A typical solar cell is made from a base wafer of arsenic-treated silicon covered by a surface layer of boron-treated silicon. When the cell is exposed to sunlight, energy from the sunlight causes electrons to move from the outer layer into the base wafer. If electrical leads are attached to the wafer and surface layer and connected, electric current will flow through them.

The principal problem with silicon solar cells is their cost. Although silicon is the most abundant element in the Earth's crust, most of it contains impurities. For use in solar cells, it must be refined to no more than one part impurity per one mil-





	Silicon	Thermal
Conversion efficiency	13.4%	12.3%
Area	55 km²	60 km²
Mass	49 500 T	51 000 T

Left, launch of a hypothetical 2-stage Space Transportation System or "Space Freighter" design proposed to deliver up to 425 metric tons to Low Earth Orbit for construction of a Solar Power Satellite. The design shown would be about 150 meters (492 feet) tall and have wings on both stages so that they can be flown back to Earth for re-use, like the Space Shuttle. Right, the two main SPS concepts under study.

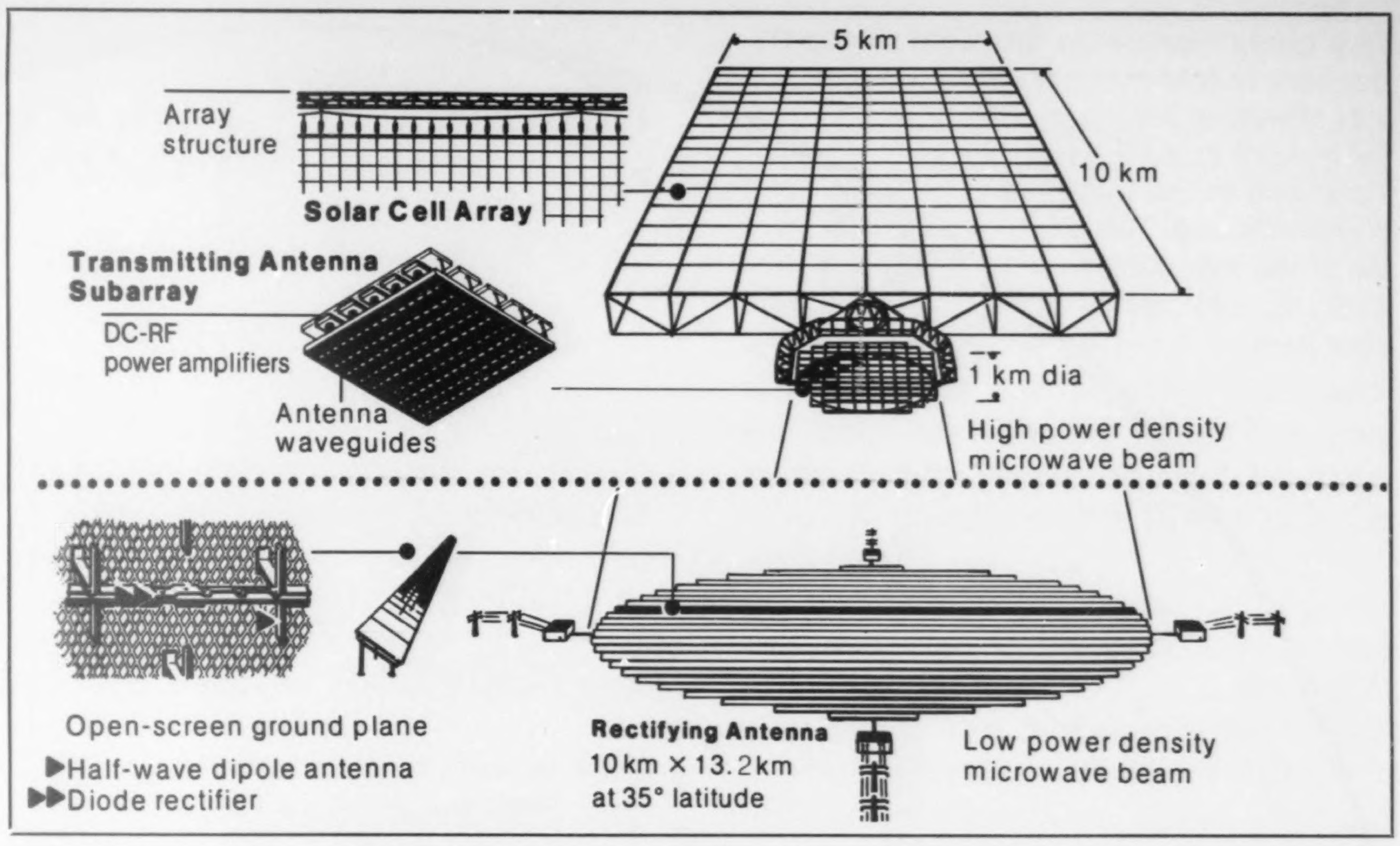
lion parts silicon. This high purity requirement has been one of the factors keeping the cost of solar cells extremely high—in some applications, as high as $300,000 per kilowatt. Over the last 25 years, researchers have reduced silicon solar cell thicknesses from 200-300 micrometers (.008-.012 inch) to 50 micrometers (.002 inch) and increased efficiencies from 11 percent to 14 percent. (The solar cells are able to convert 14 percent of the solar energy falling on them to electrical energy.) Other materials, most notably gallium arsenide, have been explored for solar cell use.

Thermal engines concentrate the Sun's energy on a small area to heat a fluid that drives a generator. They have one principle advantage over photovoltaic cells: their efficiency is expected to be at least double that of a solar cell array. The main disadvantages of the thermal engine are that it is a complex system of numerous complex moving parts, and that it requires a massive radiator system for heat dissipation. The system currently under study by the Department of Energy and NASA employs photovoltaic cells.

Whatever power generation system is used on the SPS, the electrical energy must be transmitted to Earth. At this time, microwave transmission seems to be the most likely method. Electricity generated on the SPS would be converted to microwaves and transmitted as a continuous wave beam to a large rectifying antenna array, or rectenna, on the ground. The rectenna would be made up of thousands of smaller dipole antennas, each connected to a half-wave rectifier and filter system, which would convert the microwave beam back to DC electricity.

Such a satellite would be immense. In 1978, Gordon Woodcock of the Boeing Aerospace Company described a hypothetical 10,000-megawatt SPS with a silicon photovoltaic cell area of 101 square kilometers (39 square miles) measuring more than 24 kilometers (15 miles) long and 4.8 kilometers (3.0 miles) wide. The SPS would weigh nearly 100,000 metric tons (110,000 U.S. tons).

There are several problems and unanswered questions associated with SPS development that must be answered before a commitment could be made to such a major program. One of the most serious questions concerns the biological effects of exposure to microwaves. The microwave beam must be tightly controlled to minimize the radiation hazard from microwave exposure. (A continuous-wave microwave beam—such as would be used by the SPS—presents a much lower health hazard than a pulsed beam transmitting the same average amount of power.) However, further research is needed to determine more precisely the biological effects of microwave exposure. Also, any such satellite would have to contain fail-safe systems to prevent the transmitted beam from drifting off target.



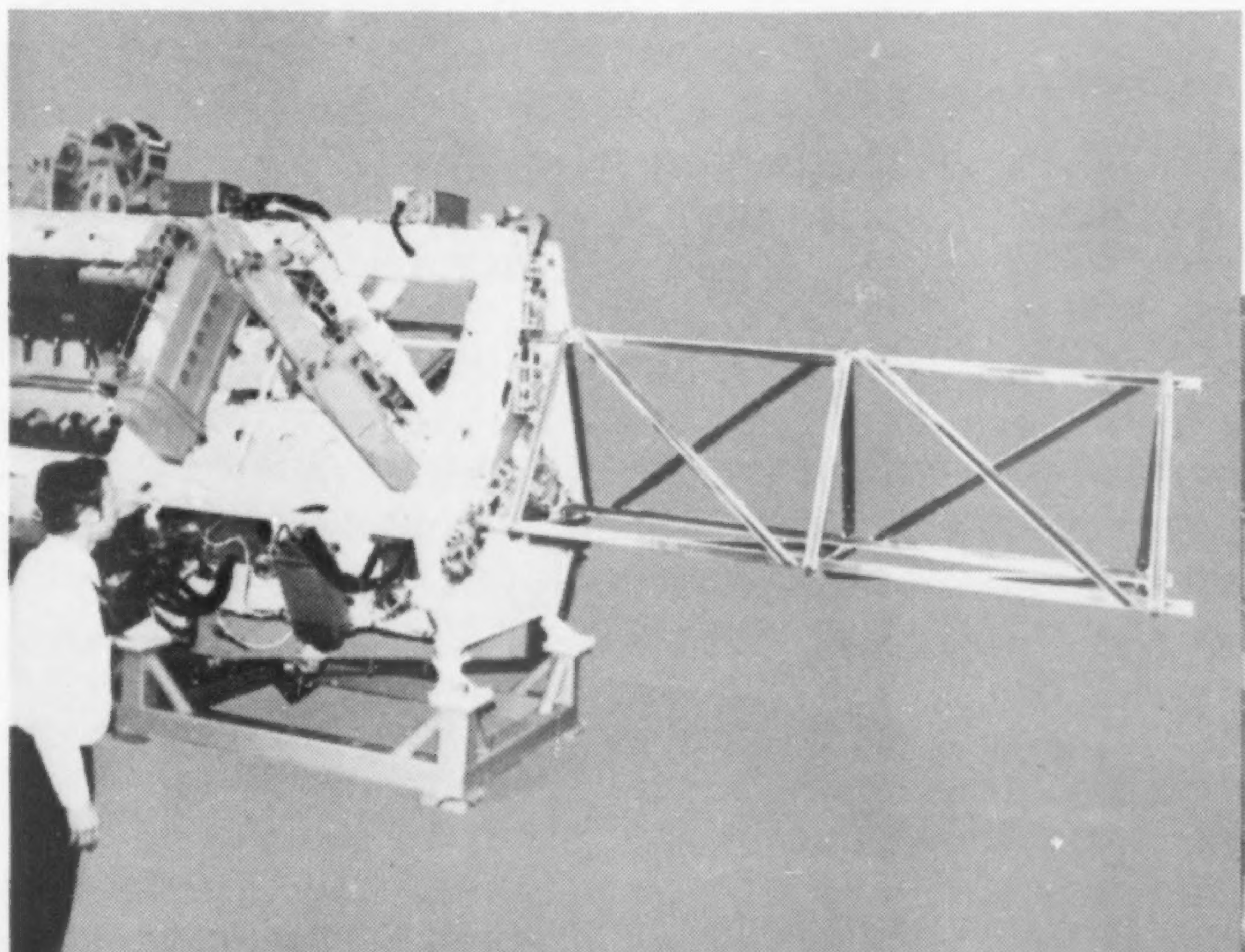
The SPS system currently under study by NASA and the Department of Energy is based on silicon solar (photovoltaic) cells.

Other problems associated wtih SPS development include the availability and cost of land for rectenna use; availability of GEO positions for SPS placement; development and construction costs; and uncertainties as to the effects of microwaves on the ionosphere.

Within this framework of SPS promise and possibilities versus problems and uncertainties, how might development of the SPS concept proceed? Over the next 20 years, the Space Shuttle will allow increased utilization of near-Earth space for a variety of projects ranging from scientific research to public services. Shuttle mission operations during this period will likely become increasingly complex and will require more electric power than the Orbiter can supply, creating a need for an orbital power module. During the 1980s, the increased orbital power requirements could be met by a 25-kilowatt power module. In the late 1980s and early 1990s, orbital power requirements are predicted to rise into the 100-kilowatt range. This need could be met by combining 25-kilowatt modules. Space power modules in the 10-megawatt range may be built in the mid-1990s to support increased space utilization.

Thus, by the end of the century, it may be possible to conduct an SPS GEO demonstration, answering many of today's questions. If all goes well with the demonstration and the commitment is made to initiate a full-scale SPS program, we could see the introduction of space-generated electricity during the first quarter of the 21st Century.

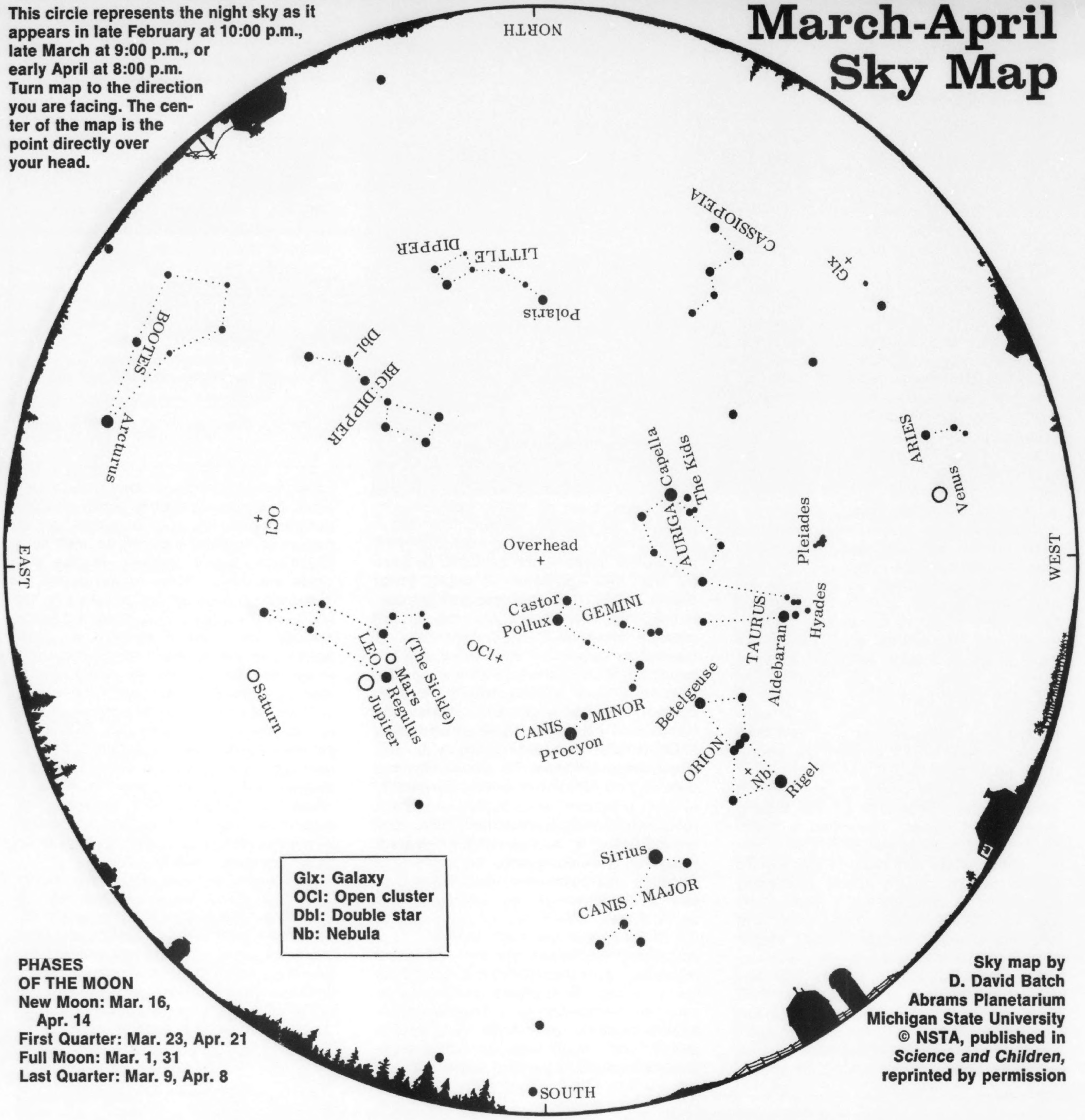
Despite its promise, the Solar Power Satellite will not be a panacea for the world's energy problems. The previously mentioned problems of GEO placement and land use limitations will prevent the SPS from fulfilling all our energy needs. However, the SPS does possess the potential of being able to supply a significant amount—some experts estimate as high as 20 percent—of our energy needs during the next century.



Left, a prototype beam-building machine capable of automatically producing a lightweight aluminum beam. Automatic fabrication is believed to be a key requirement for constructing a massive Solar Power Satellite in space. Below, an 8- by 12-kilometer receiving antenna design for converting the SPS microwave beam into DC electricity.

March-April Sky Map

This circle represents the night sky as it appears in late February at 10:00 p.m., late March at 9:00 p.m., or early April at 8:00 p.m. Turn map to the direction you are facing. The center of the map is the point directly over your head.


NORTH
EAST
WEST
SOUTH
Overhead
CASSIOPEIA
Glx
LITTLE DIPPER
Polaris
BOOTES
Arcturus
Dbl
BIG DIPPER
ARIES
Venus
Capella
The Kids
AURIGA
Pleiades
Hyades
TAURUS
Aldebaran
OCl
Castor
Pollux
GEMINI
OCl
LEO
(The Sickle)
Mars
Regulus
Jupiter
Saturn
CANIS MINOR
Procyon
Betelgeuse
ORION
Nb
Rigel
Sirius
CANIS MAJOR
Glx: Galaxy
OCl: Open cluster
Dbl: Double star
Nb: Nebula

PHASES OF THE MOON
New Moon: Mar. 16, Apr. 14
First Quarter: Mar. 23, Apr. 21
Full Moon: Mar. 1, 31
Last Quarter: Mar. 9, Apr. 8

Sky map by
D. David Batch
Abrams Planetarium
Michigan State University
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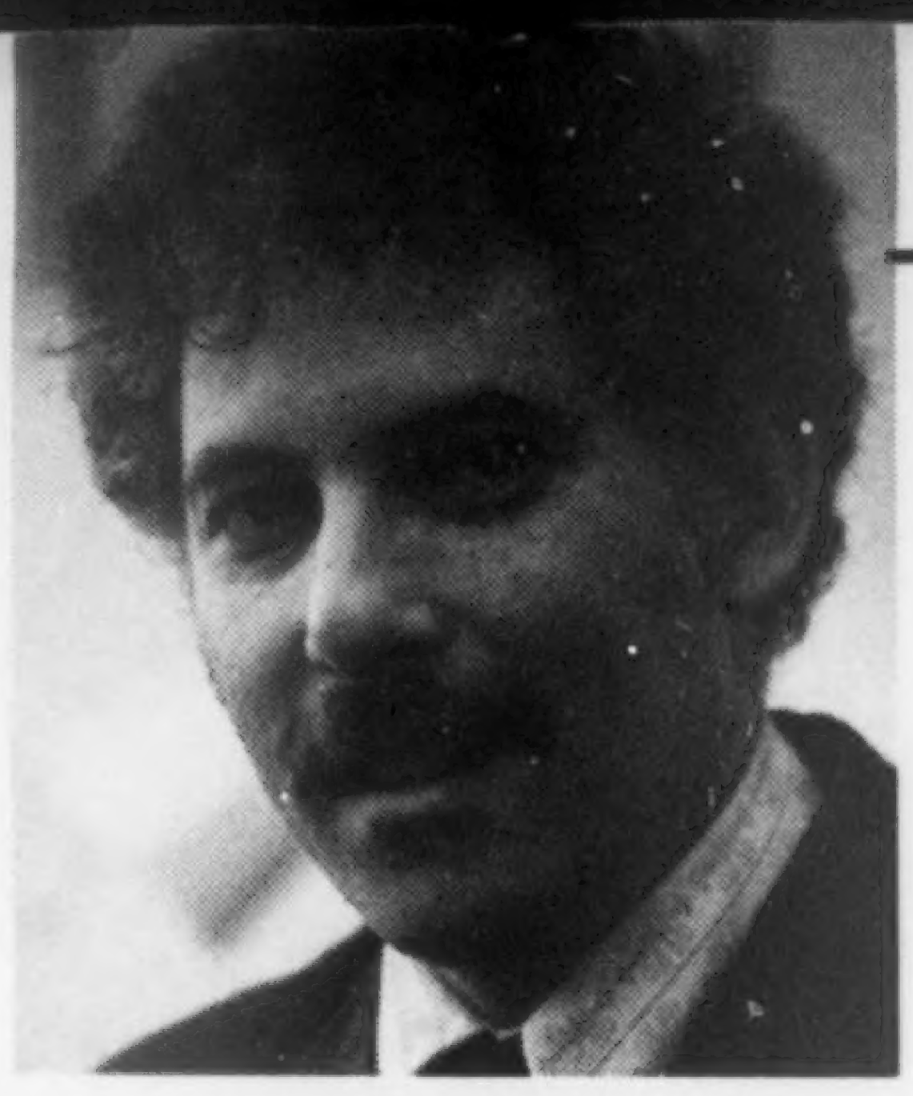
by T. H. Callen II
Production Specialist
Albert Einstein Spacearium, NASM

The most dazzling star of the night is prominent during late March and early April in the twilight sky following sunset. This is the star Sirius, located in the constellation Canis Major, the Big Dog. With the exceptions of the Sun, Moon, and the planets Venus, Mars, and Jupiter, no other celestial object is brighter.

The brightness of Sirius is due primarily to its relative nearness, only 8.7 light-years (8.4 x 10^{13} kilometers, or 5.2 x 10^{13} miles), making it a next-door neighbor to the Sun. In fact, Sirius is only 1.76 times larger than our star, about 2.45 x 10^6 kilometers (1.52 x 10^6 miles) in diameter. Although it appears to be only 7 percent as bright as Venus, the brightest planet, we know that the star in Canis Major is actually 23 times more luminous than the Sun. To put this in perspective, let's imagine that we could replace our Sun with this star. What would be the effects on the Solar System, and what would we see?

Sirius has a diameter of slightly less than twice that of the Sun. If we could place it at the center of the Solar System it would not engulf any of the planets, but it certainly would raise their temperatures. The surface of Mercury would become about twice as hot as its present temperature of 415°C (779°F). Even the most distant planet, Pluto, would show the effects, its temperature rising from —230°C (—382°F) to —192°C (—314°F). Here on Earth, life as we know it would not exist; Earth's surface temperature would climb to almost 300°C (572°F). Viewed from our desolate planet, Sirius would appear about twice as large as the Sun does to us now.

A star that looks bright is not necessarily very large in size, but may appear bright because it is relatively very close to us, as is Sirius. If we could go to Sirius and look back toward the Solar System, the Sun would appear as a faint yellow star, a little brighter than Polaris, the North Star.



OUTREACH

by Kerry M. Joëls
Chief, Education Services Division

We all can estimate the distance to the door of our room, to the end of our driveway, or from our home to our school or other common destinations. But most of us have a great deal of difficulty relating to vast distances in the Universe. How big is a galaxy? How far is it to the nearest major galaxy? How far away are quasars? How big is the Universe? All of these questions leave the average individual—and even the average teacher—casting about for a simple way to express distances that are simply not on a human scale.

Three standard units of distance exist in astronomical measurement: the astronomical unit, the light year, and the parsec.

One astronomical unit (AU) equals the mean distance between the Earth and the Sun, approximately 150 million kilometers (93 million miles). Mercury is a little less than 0.4 AU from the Sun; Pluto, approximately 40 AU. But the distance to Alpha Centauri, the nearest star, is about 300,000 AU, so a larger measuring stick is required.

Interstellar distances generally are measured in two ways. For stars that are relatively close, galactic astronomers usually measure distances in parsecs (pc). One parsec is the distance at which one astronomical unit would subtend an angle of one second (1/60th of a degree) of arc, or 31 trillion kilometers (19.2 trillion miles). Alpha Centauri is 1.3 pc away. Larger distances are expressed in multiples of 10, as in the metric system. The kiloparsec (kpc) equals 1000 parsecs.

The more conventional unit for measuring all distances in interstellar, intragalactic, and intergalactic space is the light-year. Light travels at 300,000 kilometers (186,000 miles) per second in a vacuum. In one year it travels approximately 9.46 trillion kilometers (5.88 trillion miles). Therefore, 9.46 trillion kilometers is the length of one light-year (ly). While a light-year is a great distance, galaxies and intergalactic distances are so big that they require descriptions in terms of hundreds of thousands or even millions of light-years. Humans find it very difficult to relate to 100,000 of anything, much less light-years. Large intergalactic distances often are expressed in exponential terms. For example, the Andromeda Galaxy is 2.2×10^6 ly (2.2 million light-years) from Earth.

Again, most people do not relate to exponents. So perhaps we need to develop a simpler system. An idea from the metric system may furnish a possible solution. Many people are used to working in powers of 10, using standardized prefixes to denote these multiples of standard units. One meter is about one yard. A dekameter is 10 meters. A hectometer is 100 meters. A kilometer (1000 meters) is about $\frac{5}{8}$ of a mile. The prefixes *kilo-* and *mega-* are relatively familiar, but they are rather foreign when applied to astronomical measurements in our popular literature.

To further relate these to language and use, let's develop a new system of nomenclature. Let's call the light-year a *lilly*. The distance from our Sun to the nearest star, Alpha Centauri, is a little more than four lillies. The distance to Sirius (the Dog Star) is more than 8 lillies, or almost 10 lillies. Ten lillies would be a *dilly*.

The Milky Way Galaxy is 100,000 light-years across, or 100 *killies*. The Andromeda Galaxy is 2.2 million light-years from Earth, or 2.2 *millies*. Some quasars are more than 10 billion light-years away, or 10 billies.

These measurements could be correlated with concepts that are used in any high school physics class and are being introduced at the junior high and elementary levels for metric education. This suggested system uses a standard astronomical unit of length and is fairly easy to remember. It also allows relative scaling for the construction of models of star groupings, a galaxy, galactic groupings, and galactic clusters.

We left out one measurement, you say? What is 100 light-years? That's *cilly*!

Regional Resource Program Applications Sought

The Regional Resource Persons Program is a NASM outreach program designed to prepare educators to give presentations in their respective geographic regions on major aerospace developments as exhibited in the Museum's galleries and special activities.

The next Training Session for new participants will be held in late July 1980, and will include topics on aviation and space exploration. NASM will provide to Regional Resource Persons support material such as slides, catalogues, and selected publications, plus limited public relations assistance. Participants will be responsible for their own transportation and expenses during the Training Session.

Persons interested in participating in this program should contact Janet K. Wolfe, Unit Chief, Outreach Programs, Education Division, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560 (202) 381-4202/4166. Applications must be received by April 25, 1980; notification of selection will be made the week of May 5, 1980.

Aerospace Education Conventions, Directory

The 13th Annual National Congress on Aerospace Education, sponsored by the Federal Aviation Administration, NASA, and the Civil Air Patrol, will be held March 26-29, at the Court of Flags Hotel, Orlando, Florida. For additional information, contact HQ CAP/ED, Maxwell AFB, AL 36112 (205) 293-5371.

The American Society for Aerospace Education (ASAE) plans its Second National Aerospace Education Convention July 21-25, at Florida Institute of Technology, Melbourne, Florida. For more information, contact ASAE, Suite 1303, 1750 Pennsylvania Ave. NW, Washington, DC 20006 (202) 347-5187.

Copies of the updated 3rd edition of the *Directory of Aviation/Space Education* are available now from ASAE at the address above. The *Directory*, which lists hundreds of aerospace education resources, is free to ASAE members; the cost to non-members is $5.00 per single copy, with lower prices for bulk orders.

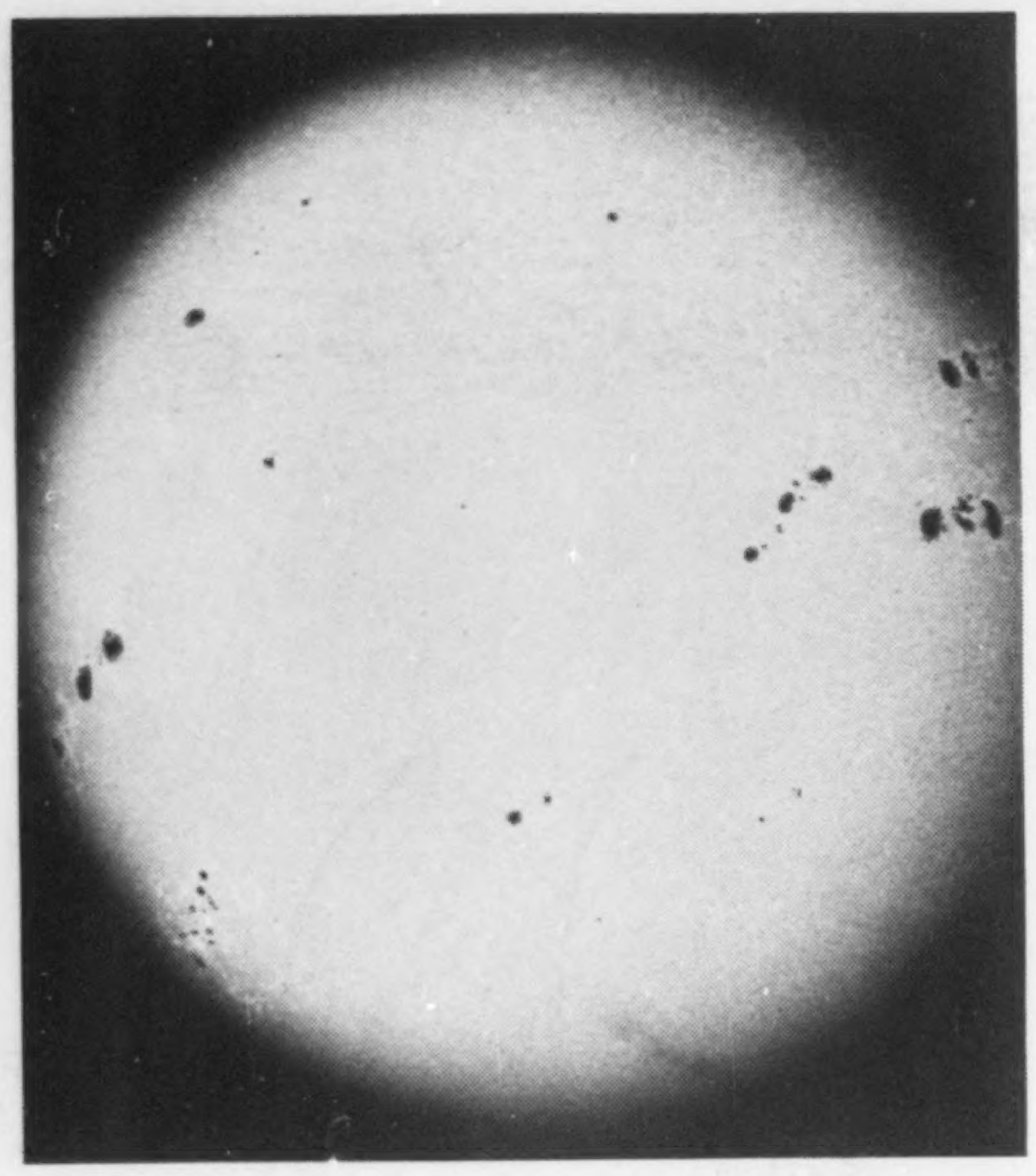
ILLUSTRATION CREDITS

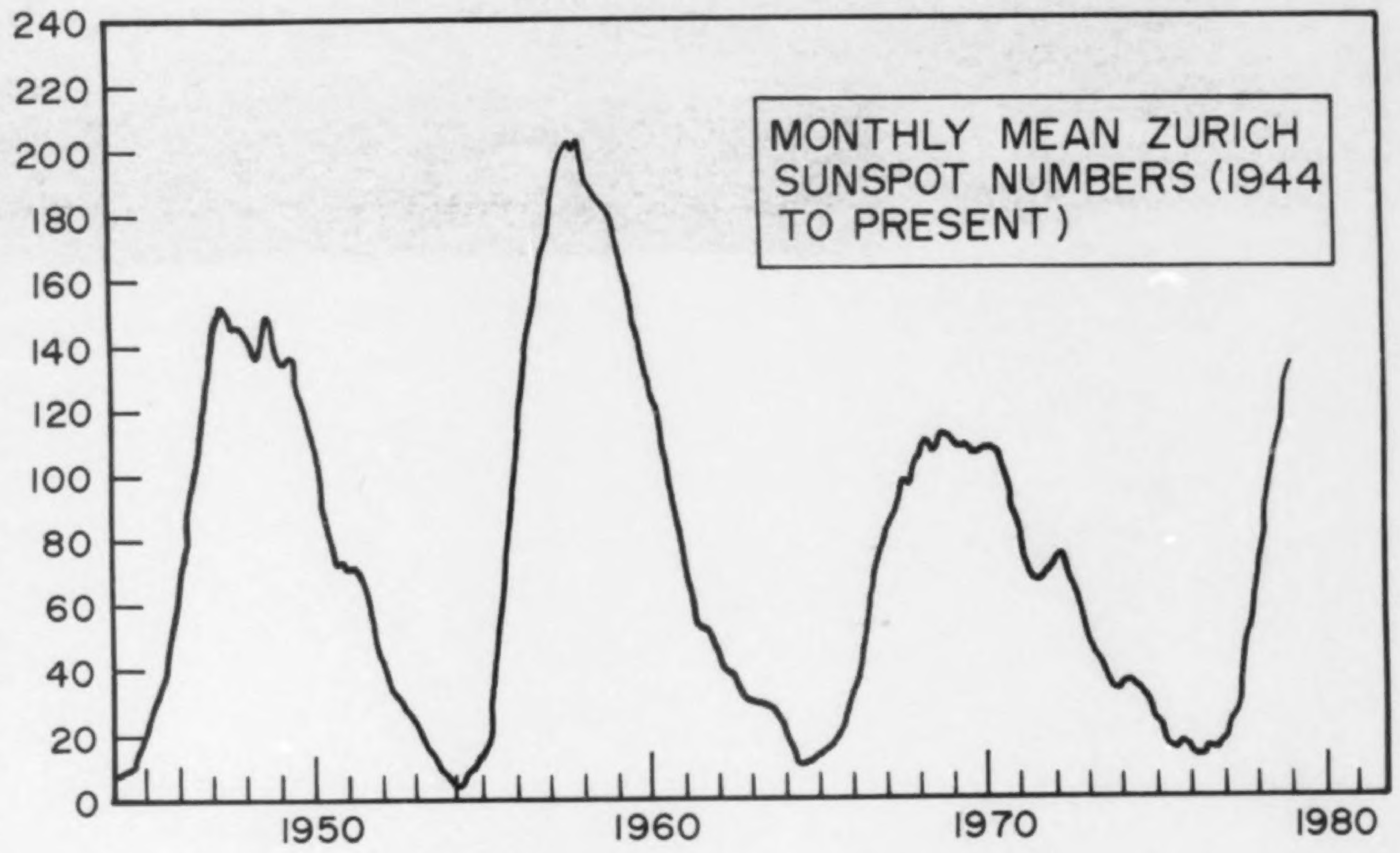
Front cover: Space construction worker, NASA; *Ole Miss*, NASM Collection. Pages 2-7, 15: NASM Collection. Pages 8-9: Vin Fiz Board Game art, Janet K. Wolfe, NASM; Cal Rodgers photos, NASM Collection. Pages 10-11: Dale Hrabak, NASM. Pages 12-13: Rectenna photo, Boeing Aerospace Company; all others, NASA. Page 16: Photo, Hale Observatories; graph by Patti Woodside, NASM, adapted from EOS, Transactions, American Geophysical Union.

THINK ALONG WITH THE ASTRONOMERS

about solar ups and downs

by Von Del Chamberlain
Astronomer, Department of Space Science and Exploration, NASM





Left: Several sunspots were visible on the solar disk when this photograph was taken, September 15, 1957. Right: A chart of the number of average sunspots observed in Zurich over a period of 35 years shows that the number of sunspots varies in an 11-year rhythmic cycle. (So do the size of the spots and related solar activity.)

Our earliest ancestors probably understood that they were totally dependent upon the Sun. Now we know much more about the day-star, but most of us probably think about it far less than the primitives did. Amid busy lives—houses and automobiles, light and air conditioning switches—we almost forget it is there. At least we did until recently. Now our new energy consciousness forces us into deeper appreciation of our natural powerplant in the sky.

Is the Sun a reliable, constant source of energy to keep Earth's living things alive? Well, not forever, and perhaps it never has been as constant as we once thought it was. Since it gives off energy, it continuously consumes its fuel supplies, and its nuclear fires eventually will shut down. Estimates suggest that it will last, essentially as we know it, for another 4 or 5 billion years. But we know that it is constantly undergoing small changes and that some of these might well affect us in detrimental ways.

We can observe some of the changes taking place in the Sun. With solar telescopes we usually see dark spots upon the visible solar disk. The regions surrounding these spots tend to be very active. The spots themselves are magnetic disturbances thousands of degrees cooler than the rest of the Sun. Near the spots, both small and large bursts, called flares, take place. Intense streams of nuclear particles, mostly hydrogen ions and electrons, shoot out from flares and can cause major terrestrial effects such as radio fadeouts, aurorae, and even power outages.

The number of spots on the Sun varies over a somewhat predictable period of about 11 years. The number rises to a maximum for four or five years, then falls toward a minimum for about six or seven years. There are currently a lot of spots and associated activity on the Sun as we rise toward a sunspot maximum expected in 1980-81.

Hoping to learn as much as possible about the active Sun, NASA has prepared a program known as the Solar Maximum Mission. This observational program will use a variety of tools, including ground-based instruments, sounding rockets, and a satellite scheduled for launch in early 1980.

The program is designed to study solar flares with combinations of devices that can measure the entire range of energy coming from the flares. Instruments on the satellite will make it possible to record flares in parts of the energy spectrum, such as x-rays and gamma rays, that do not penetrate the Earth's atmosphere. Observations of the same events made both on Earth and in space may help to explain why flares occur, how they might be predicted, and what they tell us about the future of the Sun.

As the Sun goes, so goes the Earth. Earth's ice ages and warmer periods are probably due to slight variations in the Sun's energy output. Perhaps the Solar Maximum Mission will help us better understand Earth's history and more reliably predict the future conditions so vital to our well-being and continued existence.

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